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AMERICAN PHILOSOPHICAL SOCIETY

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ON "PSYCHOLOGY AS THE BEHAVIORIST VIEWS IT."

BY E. B. TITCHENER.

(Read April 3, 1914.)

When we speak of a science, we have in mind a logically organized body of knowledge that has resulted from certain methods of attacking the problems presented by a particular subject-matter. The methods of science are all, in the last resort, observational; the problems of science are all, in the last resort, analytical. The subject-matter of a given science may be indicated in two different ways: by a simple enumeration of objects, or by a characterization of the point of view from which the science in question regards the common subject-matter of all science, namely, human experience. Thus we may say that our psychology will deal with such things as perceptions, feelings, thoughts, or we may say that psychology, dealing "in some sort with the whole of experience," is to be distinguished as "individualistic" from other sciences which are "universalistic." It is clear that a characterization of this kind, though it necessarily transcends the limits of the science in order to show how those limits are drawn, is far more satisfactory than a mere list of objects; and psychology, these many years past, has therefore had recourse to it.[1]

[1] J. Ward, "Psychology," Encyc. Brit., XX., 1886, 38 (and later); R. Avenarius, "Bemerkungen zum Begriff des Gegenstandes der Psychologie," *Vjs. f. wiss. Phil.*, XVIII., 1894, 418; H. Ebbinghaus, "Grundzüge der Psych.," I., 1897, 8 (and later editions). On the general subject, cf. E. B. Titchener, "Psychology: Science or Technology?", in *Pop. Sci. Mo.*, LXXXIV., 1914, 39 ff.

Instead, however, of calling psychology with Ward the "science of experience regarded objectively from the individualistic standpoint," or with Avenarius the "science of experience in general, so far as experience depends upon System C," or with Külpe the "science of the facts of experience in their dependency upon experiencing individuals," or something of that sort, we are accustomed to speak of it as the "science of mind." No harm would be done, if we and our readers always remembered what "mind," as used in a scientific context, must mean. Harm begins at once when we forget that scientific meaning, and start out from the commonsense or traditional significance of the word; when we equate "mind" with "consciousness," which we take as the equivalent of "awareness," and when we set off a group of "conscious phenomena" as the peculiar subject-matter of psychology. I do not think that modern psychologists can fairly be charged with neglect of their duty to correct these errors; it seems to me, on the contrary, that our leaders are painfully careful to set their house in logical order. But habits of speech are inveterate, and common sense is extraordinarily tenacious of life: small wonder, then, that misunderstandings should arise. It is, for example, a misunderstanding that has prompted the polemical paragraphs of Watson's recent articles on what, I suppose, we must be content to call Behaviorism.[2]

This doctrine, as set forth by Watson, has two sides, positive and negative. On the positive side, psychology is required to exchange its individualistic standpoint for the universalistic; it is to be "a purely objective experimental branch of natural science" in the sense in which physics and chemistry are natural sciences.[3] It is to concern itself solely with the changes set up, by way of receiving organ and nervous system, in muscle and gland.[4] It is differentiated from its sister sciences of life partly by its special point of view, partly by the goal which it strives to attain. The changes which it

[2] J. B. Watson, "Psychology as the Behaviorist Views It," *Psych. Rev.*, XX., 1913, 158 ff. (to be referred to in the future as *A*); "Image and Affection in Behavior," *Jour. Phil. Psych. Sci. Meth.*, X., 1913, 421 ff. (to be referred to in the future as *B*).

[3] *A*, 158, 176 f.

[4] *B*, 427 f.

studies are to be approached from the point of view of adjustment to environment; its categories are stimulus and response, heredity and habit.[5] Differentiation, however, is not to be understood as separation; there is now no barrier between psychology and the other "natural" sciences; in the long run behavior will appear as a matter of physical and chemical causation,[6] while nevertheless, as behavior, it is the subject-matter of the special science of psychology, to be interpreted and arranged under the rubrics just mentioned. The erection of this special science is both justified and made possible by the practical goal of behaviorism, which is the working out of general and special methods for the control of behavior, the regulation and control of evolution as a whole.[7]

On the negative side, again, psychology is enjoined by the behaviorist to ignore, even if it does not deny, those modes of human experience with which ordinary psychology is concerned, and in particular to reject the psychological method of introspection. "Consciousness in a psychological sense" may be dispensed with;[8] consciousness, in the sense of a tool or instrument with which all men of science work, may be utilized by the new psychology without scruple and without examination.[9] Imagery, the "inner stronghold of a psychology based on introspection," is denied outright; one of Watson's "principal contentions" is "that there are no centrally initiated processes."[10] And if consciousness may be dispensed with, self-observation and the introspective reports that result from it are to be treated in even more summary fashion; they are to be "eliminated."[11] There will be no real loss; for most of the essential problems with which psychology as an introspective science now concerns itself are open to behaviorist treatment, and the residue may "in all probability be phrased in such a way that refined methods in behavior (which certainly must come) will lead to their solution."[12]

[5] *A*, 167, 177.

[6] *A*, 173, 177.

[7] *A*, 158, 162, 168, 177.

[8] *A*, 161, 163, 175, 176 f.

[9] *A*, 175, 176.

[10] *B*, 423. The statement is qualified in a footnote; I return to the point later.

[11] *B*, 428; *A*, 158, 163, 166, 170, 175.

[12] *A*, 177; *B*, 428.

Such, in outline, is "psychology as the behaviorist views it." Watson, of course, goes into some amount of detail, offering illustration and personal explanation, as well as attacking the method and problems of current psychology. But before I follow him on these various paths, I should like to record two general impressions that the reading of his articles has made upon me. The first impression is that of their unhistorical character; and the second is that of their logical irrelevance to psychology as psychology is ordinarily understood.

I call the articles unhistorical because they give no hint that any similar revolt against an established psychology had taken place earlier in psychological history. Yet one need go no farther back than Comte to find a parallel. Comte's rejection of introspection has often been referred to: let me now quote another passage in which he sums up his attack upon ideology.

"It is evident, first, that no function can be studied but with relation to the organ that fulfils it or to the phenomena of its fulfilment; and, in the second place, that the affective functions, and yet more the intellectual, exhibit in respect of their fulfilment the peculiar characteristic that they cannot be directly observed during the actual course of this fulfilment, but only in its more or less immediate and more or less permanent results. There are then only two different ways of studying scientifically such an order of functions: we must either determine, with all attainable precision, the various organic conditions on which they depend,—and this is the chief object of phrenological physiology; or we must observe the consequence for conduct of intellectual and moral acts,—and this belongs rather to natural history . . .; these two inseparable aspects of one and the same subject being, of course, always so conceived that each may throw light on the other. Thus regarded, this great study is seen to be inseparably connected on the one hand with the whole . . . of natural philosophy, and especially with the fundamental doctrines of biology; and, on the other hand, with the whole of scientific history, of the animals as well as of man, and even of humanity. But when, by the pretended method of psychology, we discard absolutely from our subject-matter the consideration both of the agent and of the act [that is, of the organ of function and of the result of its exercise], what more is there left to occupy the mind than an unintelligible logomachy, in which merely nominal entities are everywhere substituted for scientific phenomena . . .? The most difficult study of all is thus placed at once in a state of complete isolation, without any possible point of support in the simpler and more perfect sciences, over which it is proposed, on the contrary, to give it sovereign rule.

On these two points, all psychologists, however extreme their differences in other regards, are found to agree."[13]

Not Watson himself could be more outspoken or more severe! But we need not go back to Comte and the thirties; we need go only to Cournot and the year 1851. After a sharp criticism of introspection, Cournot writes:

"So we see that the most useful observations on the intellectual and moral nature of man, observations gathered not by philosophers disposed to theories and systems, but by men gifted with the true spirit of observation and prepared to grasp the practical side of things,—by moralists, historians, men of affairs, legislators, instructors of youth,—have not as a rule been the fruit of a solitary contemplation and an internal study of the facts of consciousness, but far rather the result of an attentive study of the behavior (*conduite*) of men placed in various situations, subjected to passions and influences of all sorts."[14]

Here we are hardly without the circle of those "fifty-odd years" which Watson believes—how mistakenly!—have been "devoted to the study of states of consciousness."[15] It would not be difficult to cross that line;[16] but it is unnecessary. My point is that Watson's behaviorism is neither so revolutionary nor so modern as a reader unversed in history might be led to imagine; and that as psychology has weathered similar proposals in the past,—and, I hope and think, has benefited by the storm,—so also it may weather and be benefited by this latest trial of its staunchness.[17]

[13] A. Comte, "Cours de philosophie positive," III., 1838, 774 ff.; the translation of H. Martineau ("The Positive Philosophy of Auguste Comte," 1856, 383 f.) is here inadequate. The polemic against introspection will be found in "Cours," I., 1830, 34 ff.

[14] A. A. Cournot, "Essai sur les fondements de nos connaissances," etc., II., 1851, 319.

[15] *A*, 174. I have shown in my "Experimental Psychology" that the experimental period falls into fairly well-marked sub-periods.

[16] I have especially in mind Lange's chapter on "Scientific Psychology" (1866) and Maudsley's on the "Method of the Study of Mind" (1867 and later).

[17] "Should human psychologists fail to look with favor upon our overtures and refuse to modify their position," Watson writes, "the behaviorists will be driven to using human beings as subjects and to employ methods of investigation which are exactly comparable to those now employed in the animal work" (*A*, 159). The "overtures" seem to consist in the familiar "Ducky, ducky, come and be killed!" But, that apart, why should anything

The second general impression that I record is that of the logical irrelevance of Watson's programme to what is currently called psychology. For suppose that that programme were carried out to its last detail: how would introspective psychology be affected? Why, those who were interested in the method and results of introspection would simply start out where Watson had left off; the universalistic psychology being completed, it would be in order for the individualistic to be begun. A shift of standpoint over against the world of experience means the appearance of a new subject-matter, or (more strictly) of a new aspect of the common subject-matter; and any one aspect has the same claim to scientific consideration as any other; nor is there in science a Congregation of the Index to allow this and to forbid that. The behaviorist may, if he will, ignore "consciousness in a psychological sense" he may use consciousness as a tool without making it "a special object of observation" there is none to say him nay; but why should not some one who is not a behaviorist scrutinize what he has ignored, and try to find out empirically of what materials this particular tool is made? Logically, so far as I can see, behaviorism is irrelevant to introspective psychology. Materially, I believe that psychology will be furthered by it, since increased knowledge of the bodily mechanisms, of anything that pertains to Avenarius' System C, means greater stability of certain parts of the system of psychology. Neither logically nor materially can behaviorism "replace" psychology.

Impressions, however, must give way to closer argument: we must view Watson's articles at shorter range. And we shall, perhaps, make most progress if we begin with his pronouncements regarding the failure of experimental psychology.

Psychology, we are told, has failed signally, during the fifty-odd years of its existence, to make good its claim as a natural science. Its present condition is chaotic. The chances are that such ques-

that the "human psychologist" does or fails to do "drive" the behaviorist to do anything? I hope that Watson will find the opportunity to employ human subjects; I hope that he will find them (he will pardon the word) intelligent; I shall be honestly interested in his results.

tions as those of the extensive attribute of auditory and the intensive attribute of visual sensations, or the differences obtaining between sensation and image, will be debated two hundred years hence as inconclusively as they are debated today. Psychological method is esoteric. It has proved unable to grapple with such matters as imagination, judgment, reasoning, conception; these topics have simply become threadbare with much handling. Functional psychology is at fault no less than systematic and structural psychology. Only those "branches of psychology which have already partially withdrawn from the parent," and which are consequently less dependent upon introspection,—experimental pedagogy, the psychology of drugs, the psychology of advertising, legal psychology, the psychology of tests, and psychopathology,—are vigorous growths. The complete elimination of introspection from these disciplines will make their results still more valuable, and will keep them—as psychology itself emphatically is not—in touch with "problems which vitally concern human interest."[18]

That, I believe, is a fair statement of Watson's position; it is given largely in his own words. I have to reply, first, that fifty-odd years is not necessarily a long period in the history of an experimental science. It is not long, of course, regarded as mere duration: for it is in the sixteenth century that "the physicist abandons scholastic speculation and begins to study nature in the language of experiment,"[19] while it is only in the middle of the nineteenth that psychology becomes experimental. It might be long, in a transferred sense, if it were crowded with workers: but the number of productive students in "systematic, structural and functional" psychology does not compare with the number in physics or chemistry.[20] Has Watson, I wonder, ever counted the number of experimental papers that deal with imagination, judgment, reasoning and conception? It is notoriously difficult to trace beginnings; but we shall not

[18] *A*, 163, 176; 165; 164; 163; 173 ff.; 165; 169 f.; 170, 176.

[19] F. Cajori, "A History of Physics," 1899, 27.

[20] Mr. H. G. Bishop has kindly listed for me the experimental papers in psychology, physics and chemistry recorded in the last five volumes of Fock's *Bibliographischer Monatsbericht*. The ratio is approximately 1 : 9.5 : 44. Account is here taken of the psychological studies to be found under "Medizin," as well as of those under "Philosophie und Psychologie."

have gone far wrong if we date the first overt attempts to bring these complexes under experimental control from 1902, 1901, 1908 and 1903 respectively,—if we say, at any rate, that their experimental study belongs to the present century. And we have already worn such topics threadbare? I should rather judge that we have hardly touched their fringe. How many decades or centuries they will engage the attention of psychologists, I do not know; the important thing is that we should do thoroughly such work upon them as can be compassed in a generation. Our descendants may ask so much of us; but we owe them nothing more; and though I also hope that two hundred years hence other questions may have replaced those of visual attributes and imaginal characters, of orientation in the rat and of the homing sense of terns, I am far more deeply concerned to sift the materials of discussion than to hurry debate to a conclusion.[21]

There remain the seceding branches, experimental pedagogy and the rest. In their regard, I think, the unhistorical nature of Watson's paper renders his exposition seriously misleading; it is psychology, and not behaviorism, that has shaped their course; and it is psychology, and not behaviorism, that they still look to for guidance. Meumann's *Lectures,* for example, are offered as an introduction to experimental pedagogy and its psychological foundations; the work is penetrated with psychology; the pedagogical experiment is said to be "for the most part the psychological experiment applied to the developing and working school-child."[22] But it is largely owing to Meumann that experimental pedagogy flourishes. Rivers chose the subject of his Croonian Lectures with the desire to show that experimental psychology may be of service to medicine.[23] Stern, who

[21] It is, perhaps, beyond my province to defend functional psychology; but I should not like to have written this sentence: "It is rather interesting that no functional psychologist has carefully distinguished between 'perception' (and this is true of the other psychological terms as well) as employed by the systematist, and 'perceptual process' as used in functional psychology" (*A,* 165). What, then, of Brentano, and of the many psychologists who have been inspired by him?

[22] E. Meumann, "Vorlesungen zur Einführung in die experimentelle Pädagogik und ihre psychologischen Grundlagen," I., 1911, 27.

[23] W. H. R. Rivers, "The Influence of Alcohol and Other Drugs on Fatigue," 1908, 1, 121.

stands to the psychology of testimony in somewhat the same relation that Meumann bears to experimental pedagogy, is also through and through psychological. Binet, whose name is inseparably connected with the psychology of tests, might fairly be called an extremist in his devotion to introspection. Pick demands "eine psychologische Vertiefung der Aphasielehre," and makes constant use of laboratory material: "es ist höchste Zeit dass die Pathologie endlich von diesen Dingen Kenntnis nehme."[24] It is worth noting that Meumann, Stern and Binet—the men to whom we are chiefly indebted for experimental pedagogy, the psychology of testimony, and mental tests—would all have been brushed aside by Watson, a few years ago, as typically introspective psychologists; and it is worth noting also that they themselves look upon this later work, not as the negation of their psychological training, but as its direct extension and practical fulfilment. It is worth noting, again, that a man of Pick's authority ascribes the unprogressive state of psychopathology in large measure to an ignorance of current introspective psychology, and himself makes definite use of the "imageless thought, attitudes, and *Bewusstseinslage,* etc.," which Watson contemns.[25] I am not here depreciating behaviorism; but I think there is no justification for behaviorism's depreciation of psychology.[26]

[24] A. Pick, "Die agrammatischen Sprachstörungen: Studien zur psychologischen Grundlegung der Aphasielehre," 1913, I., 11, 58, etc.

[25] *A,* 163. The psychology of advertising, so far as it has gone, bears out my argument. Cf. D. Starch, "Principles of Advertising," 1910; W. D. Scott, "The Psychology of Advertising," 1912; W. A. Shryer, "Analytical Advertising," 1912; H. L. Hollingworth, "Advertising and Selling; Principles of Appeal and Response," 1913. The psychology of these works is not always of the severest type; but the attitude of the writers is unmistakably psychological.

[26] I have said nothing of the "esoteric" nature of introspection, because I have dealt with that charge in recent articles (*American Jour. Psych.,* XXIII., 1912, 427 ff., 485 ff.). In referring to my own work, Watson falls into the common mistake of confusing observation with theory. If he were to serve as observer in one of our studies on attention, he would have no difficulty, after a little practice, in passing the sensory judgments that we required of him. That is a matter of observation and report. Whether he would, after such participation in the actual work, accept our setting and interpretation of the results is another and a different question.

In his second article Watson discusses two topics "which may seem to many to be stumbling-blocks in the way of a free passage from structuralism to behaviorism." These topics, one sees with some surprise, are Image and Affection: with surprise, I say, because we had already been prepared to ignore consciousness and to eliminate introspection. It turns out, however, that the difficulty is methodological. For if the physiological counterpart of the image is cortical, then that mode of behavior which is to replace the introspective psychology of thought lies inaccessible within the skull. If "affection is a mental process distinct from cognition (*sic*)," then affection cannot be an "organic sensory response." So image and affection have to be dealt with; and Watson deals with them faithfully; the existence of the image is denied outright, and affection is carried willy-nilly to the periphery.

Watson offers three bits of evidence for his contention that "there are no centrally initiated processes." In the first place there are experimentalists who maintain that thought-processes may go on independently of imagery. In the second place there is no objective experimental evidence of the presence of different types of imagery. In the third place even the structuralists seek to reduce higher thought-processes to groups of obscure organic processes. I think that these arguments can be met in terms almost as brief as their statement. In the first place, the view that thought is independent of imagery hardly constitutes a presumption that there are no central processes of any kind. In the second place Fernald does not deny type, but asserts that "an individual's type can be adequately indicated only by an extended statement";[27] and that is the opinion now generally held by psychologists. But let us suppose that types cannot be indicated at all: by what logical inference may we pass from this negative finding to the denial of imagery? In the third place the reduction of thought to organic processes always implies in the background a cortical set corresponding to the *Aufgabe*. Watson, nevertheless, denies that there are centrally initiated processes, and proposes to find the behaviorist equivalent of thought in movements,

[27] M. R. Fernald, "The Diagnosis of Mental Imagery," *Psych. Monogr.*, XIV., 1, 1912, 128 ff.

chiefly, of the larynx. In the same way he finds the behaviorist parallel of affective process in tumescence and shrinkage of the organs of sex. These views are put forward as matters of hypothesis and of personal conviction, though they are also put forward with some confidence. Time and trial will prove their value.

Meanwhile, it would seem that Watson has in both cases, in the case of image as in that of affective process, overshot the logic of his position. The negative argument as regards imagery can never be proved in formal logic, to say nothing of the fact that it conflicts with a very large body of positive observation.[28] Logical confusion is shown plainly enough in the following remark: "I may have to grant a few sporadic cases of imagery to him who will not be otherwise convinced, but I insist that the images of such an one are sporadic, and as unnecessary to his well-being and *well-thinking* as a few hairs more or less on his head." If there are any images at all, then there are (on Watson's own showing) centrally initiated processes, and behaviorism is bound to take account of them; and his personal assurance that they are unnecessary to thought is offset at once by the assurance of Watt and others that thought does in fact go on in imaginal terms.[29] Science is concerned with empirical facts; and for the individual man of science to "insist" that certain facts of observation may be cancelled without loss to the science to whose subject-matter they belong is to incur, at the very least, the charge of a certain rashness of behavior.

Another logical objection seems to me to lie against Watson's procedure in this second article. All science works upon assumptions, psychology no less than the other sciences. Münsterberg, for instance, is wholly within his logical rights when he assumes that all conscious contents, without exception, may be transformed into sensations:[30] given his premises, they must be so transformed. Be-

[28] I quote a recent statement: "From an actual count of factors present in the recall of ten of our problems, we estimate that our investigation embraces approximately 200,000 images. . . . Of all our introspective data, about ninety per cent. are visual images" (E. O. Finkenbinder, *Amer. Journ. of Psych.*, XXV., 1914, 81).

[29] H. J. Watt, "Experimentelle Beiträge zu einer Theorie des Denkens," *Arch. f. d. ges. Psych.*, IV., 1905, 312; cf. my "Thought-processes," 1909, Lect. I.

[30] H. Münsterberg, "Grundzüge der Psychologie," I., 1900, 331.

haviorism would be equally within its logical rights in assuming that all central processes may be transformed into peripheral: given Watson's premises, they must be so transformed. But you cannot eat your cake and have it too. You may bring up facts in support of your choice of assumptions; and you may show the scientific results to which those assumptions lead; you may not, surely, offer these results, even hypothetically, as facts in proof of your assumptions. If we take up Münsterberg's position, we find nothing but sensations to work upon; but that is not evidence that Münsterberg's position is well-chosen. If we take up Watson's position, we find, perhaps, laryngeal movements and changes in the state of the sex-organs; but that discovery gives no logical support to the principles of his behaviorism.[31] It is, indeed, obvious that, if the larynx and the sex-organs prove refractory, the behavioristic equivalents of image and affection must just be put—hypothetically, again—somewhere else; and so on, and so forth; for it is a logical consequence of the position that somewhere on the periphery the required movements and changes are to be discovered; and the periphery is complex enough to suggest any number of localizations.[32]

[31] I do not deny that the empirical consequences of a particular theoretical attitude may serve *materially* to justify that attitude for its special day and generation; men have often worked successfully for a time though the logical foundations of their work were insecure. But the permanence of the structure depends on the solidity of the foundations, and to shirk their inspection is only to make "more haste" for the sake of "less speed."

[32] The reduction of pleasantness-unpleasantness at large to sheer sex-feeling is to me nothing else than nonsensical. But, like Watson, "I shall not attempt to develop the point further at the present time." It is, however, necessary to point out that the method of expression is not so ill bestead as Watson declares it to be. In his latest tabulation (*Arch. f. d. ges. Psych.*, XXXI., 1914, 27 ff.), E. Leschke finds 90 per cent. of substantial agreement in the investigations which he considers. The two principal sources of error are a disregard of neurasthenia and of vasomotor anomalies and—an inadequate psychological training of experimenter and observer!

I may, perhaps, be expected to say a word on Watson's criticism of my own doctrine of affection. The doctrine itself, I regret to say, he has not understood. But he has also mistaken the motives which led me to adopt it. My view that affection lacks the attribute of clearness is, he says, an assumption "arrived at largely in the interest of obtaining a structural differentiation between sensation and affection" (*B*, 426). As if a structural system would not be greatly simplified and, as system, improved by the reduc-

But the argument does not end here. I have formulated my criticism as if Watson's views were rigorously worked out, and as if his centrally initiated processes were conceived rigorously as physiological. That is, evidently, not the case; these processes are, in Watson's thought, both mental and physical; not only are brain-changes to be transformed into their equivalent peripheral changes, but the facts of psychology (as psychology is currently taken) are also to be carried, by way of behavioristic substitution, to the bodily periphery. The "required" peripheral changes are required—by the thoughts and emotions of an introspective psychology! And with that, by definition, behaviorism has nothing to do. The confusion here is plain, and the critical point need not be further labored. I must add, however, in the same connection, that I do not understand Watson's attitude to sensation. He admits that there are special cutaneous nerves "which mediate pain." He thinks that imagery is the key of the introspective stronghold: "all the outer defences might be given over to the enemy." These utterances seem to imply that sensation, if not part of the subject-matter of behaviorism, is at least neutral ground between that and introspective psychology; whereas, in the earlier article, sensation was definitely assigned to psychology.[33] Logically, I do not see how a behaviorist, in Watson's sense, can know anything of pain. I regard sensations as introspective material on precisely the same level with images; and I should challenge the behaviorist to replace or duplicate, in his universalistic terms, the various observations recorded, for example, in Stumpf's "Tonpsychologie," or in Hering's new "Lichtsinn."[34]

tion of affection to organic sensation! I only wish that I could see my way clear to it. J. R. Angell recognized the temptation in *Philos. Rev.*, XIX., 1910, 322; Watson's comment puts the cart before the horse.

[33] *A*, 164.

[34] C. Stumpf, "Tonpsychologie," I., 1883, Vorwort; E. Hering, "Zur Lehre vom Lichtsinne" [1874], 1878, 72, 106. "Der . . . Weg, welcher von den Aetherschwingungen ausgeht, hat bis jetzt, so weit es sich nicht blos um die Schicksale der Lichtstrahlen in den optischen Medien, also lediglich um eine Application der physikalischen Optik auf's Auge handelte, noch zu keinem Ergebnisse geführt"; "Ich war immer der Ansicht, dass die grossen Aufgaben, welche der Physiologie und insbesondere der Nervenphysiologie gestellt sind, am zweckmässigsten, ähnlich einer Tunnelbohrung, von zwei Seiten zugleich in Angriff genommen werden, nämlich nicht nur von der physikalisch-chemischen Seite, sondern auch von der psychischen."

All in all, this paper on Image and Affection, while it is written with a truly scientific candor, shows, I think, that the author has imperfectly grasped the logic of the situation which he has himself created.

In trying, now, to appraise Watson's proposals as a whole, we must begin by clearing them of their personal and accidental accompaniments. Watson demands a psychology "which concerns itself with human life" and whose "problems vitally concern human interest." He ascribes to such a psychology the practical goal of the control of behavior, the regulation and control of evolution in general; that is to say, he connects it with euthenics and eugenics. These expressions give his proposed psychology the stamp of a technology: for science goes its way without regard to human interests and without aiming at any practical goal; science is a transcription of the world of experience from a particular standpoint, deliberately adopted at the outset and deliberately maintained; the pursuit of a practical end is the earmark of a technology. And how does that matter in the present context? It matters very greatly. Watson is asking us, in effect, to exchange a science for a technology; and that exchange is impossible; for a technology draws not upon one but upon many sciences, and draws upon many other sources than science; and so the striking of a balance-sheet between a given science and a given technology is out of the question. I said above that behaviorism can never replace psychology because the scientific standpoints of the two disciplines are different; we now see that Watson's behaviorism can never replace psychology because the one is technological, the other scientific. This technological coloring, while it strengthens the emotional appeal of Watson's plea, is nevertheless not of the essence of behaviorism. The behaviorist's position, as we shall see, may be outlined in the plain black and white of science.

The two articles are characterized, again, by the recurring note of hurry, of impatience. Fifty-odd years gone, and we have accomplished so little: two hundred years, and shall we have accomplished much more? Surely it would be well to sweep the field clear, to forget the past, and to start the race anew! But all reformers, I

suppose, are likely to be impatient; and their impatience does not affect the value of their proposed reforms. We need not regard this hurry, either, as of the essence of behaviorism. Watson himself, in less fervid mood, might not grudge us a little time for the study of his plans,—would even recognize, I believe, that our hasty acceptance of them, without due consideration, must be more dangerous than a reasonable delay.

So we come at last to behaviorism itself; and what I take that to be I can best indicate by a parallel. In the disciplines which we call physiological psychology and psychophysiology we are interested, with slight difference of emphasis, in the two aspects of certain phenomena of the living organism; we seek to couple physiological with psychological, psychological with physiological, and so to get a complete description of the psychophysical. We may, now, in just the same way, speak of biological psychology and of psychobiology; indeed, those terms are already in use, and their general significance is plain. But here is the context to which behaviorism, if I understand it aright, must of necessity belong; it is the biological side of a biological psychology or of a psychobiology; I cannot make it more, and I do not think that its practitioners can make it less. The argument is as follows:

The behaviorist, as Watson describes him, also studies certain phenomena of the living organism. In theory, he may study these phenomena in either of two different ways. He may regard them as phenomena simply, as last facts, as things given, as phenomena to be taken at their face value and described and explained in their own right: then, he is working in what we are accustomed to call biology; he has adopted no new standpoint and needs no new name. Or again he may regard them as symptomatic; as reporting, expressing, indicating, leading up to something beyond themselves; as claiming detailed study, not only in their own right as data of biology, but also because of this further and specific character of report or expression. Here is ground for a discipline other than biology; a novel point of view has been attained. At once, however, the question arises: What, then, is it that the phenomena report or express? Of what are they symptomatic? The answer seems obvious: they are symptomatic of

behavior. And the answer seems satisfactory—until we remember that the phenomena, by hypothesis, *are* behavior, "behavior material," "behavior data," and that a phenomenon cannot both "be" and "be a symptom of" the same thing. I see no way out of this dilemma. Either the behaviorist is just biologist; and in that case he has no nearer relation to psychology than have his coworkers who are content to call themselves biologists: or the behaviorist sees expression where the biologist sees ultimate fact; and in that case he may equally well be called psychobiologist, seeing that the phenomena expressed or reported by the organic changes which he studies cannot be anything else than psychical.[35]

But if this conclusion is sound, it means two things. It means that behaviorism is correlated with a psychology, with some sort of psychology in the usual sense; and it means that behaviorism must take account of all kinds of organic changes, and not merely of those occurring at the periphery. I believe that both of these consequences must be accepted. Consider again, for example, Watson's reduction of thought to delicate movements of the larynx: those movements are movements of incipient or vestigial articulation. But words, as Watson seems to have forgotten, are also meanings; and meanings take us either to the nervous center—or to psychology; they take us, in fact, to both. Moreover, the very problem of these laryngeal movements is given to the behaviorist by psychology: how would he have lighted on the idea of transforming thought into movement unless psychology had made him acquainted with thought? I do not say that the incentive will come always or must necessarily come from the psychological side; there will be give and take; but it is none the less clear that behaviorism and psychology are, in this context, correlative; and that though an individual student may wisely and successfully confine himself to the study of behavior,—yes, and may all his life maintain a polemical attitude to psychology proper,—it is yet impossible to have a science of behaviorism independent of all psychology. It is equally impossible, of course, within the same context of psychobiology, to have an independent science of psychology; the two halves are essential to the single whole; and the psychology of

[35] Cf. with this paragraph *A*, 158 ff.

the behaviorist will, in matters of selection, emphasis, arrangement, terminology, perspective, differ from general psychology just as behaviorism itself differs from general biology.[36]

We thus conclude that to say, as was said above, "psychology would begin where a completed behaviorism left off," is really to say too little. The psychology which is correlated with behaviorism begins when behaviorism begins, and the fortunes of the two are bound up in the same bundle. Psychobiology will run the same course as psychophysiology and psychophysics. It is now, I suppose, in its first phase, when pioneer work brings in gross and tangible returns. Next will come the period of revision, of elaboration of details,—a period of discouragement, perhaps, as the former was a period of elation. And then will follow the period of slow and steady progress, varied by a certain amount of wholesome interruption. Meanwhile introspective psychology, which is now entering upon this third stage of its scientific career, will go quietly about its task, wishing the new movement all success, but declining—with the mild persistence natural to matters of fact—either to be eliminated or to be ignored.

[36] At this point we become involved in the controversy regarding the possibility of an "animal psychology." I have no wish to avoid that issue, though I must postpone its full discussion for another time. I believe that an animal psychology is definitely possible; I think that with the law of continuity as basal presupposition, and with the argument from analogy for use in the concrete case, the science may be established. Meantime I have elsewhere expressed my agreement with Watson that there can, in strictness, be no objective criterion of the psychical (*A*, 161).

THE VALENCE OF NITROGEN IN AMMONIUM SALTS.

By WILLIAM A. NOYES and RALPH S. POTTER.

(Read April 24, 1914.)

During the early years of the development of the theory of valence many chemists held the view that each element has an unvarying valence. The apparent change of valence in nitrogen from ammonia to ammonium salts and in phosphorus from phosphorus trichloride to phosphorus pentachloride was explained by calling the ammonium salts and the pentachloride molecular compounds, as distinguished from ammonia and the trichloride, in which the true valence of the elements was supposed to be shown. This view received support from the dissociation of ammonium salts and of phosphorus pentachloride in the gaseous state. Gradually, with the demonstration that phosphorus pentachloride volatilizes in part unchanged, that phosphorus pentafluoride, PF_5, has a vapor density corresponding to its formula and, in general, that dissociation in the gaseous state does not correspond to any rational distinction between unitary and molecular compounds the view that elements may show a varying valence in their compounds and that nitrogen and phosphorus are sometimes trivalent and sometimes quinquivalent, came to be generally accepted.

More recently Werner[1] has proposed a modified molecular formula for ammonium chloride, $H_3N..HCl$. By this formula he intends to indicate that in the ammonium salts the nitrogen atom retains a normal valence of three but that the nitrogen atom of the ammonia and the hydrogen atom of the hydrochloric acid are held together by secondary ("Neben") valences, the hydrogen and chlorine of the acid retaining essentially the same relation to each other as in the free acid.

[1] See "Neuere Anschauungen auf dem Gebiet der anorganischen Chemie," p. 96 (1905).

An amino acid may, theoretically, assume in the aqueous solution the following forms: (*a*) the free acid, $R\left\langle\begin{matrix}CO_2H\\NH_2\end{matrix}\right.$; (*b*) a cyclic salt, $R\left\langle\begin{matrix}CO\\NH_3\end{matrix}\right\rangle O$, or according to Werner, $R\left\langle\begin{matrix}CO-O\\ \vdots\\NH_2-H\end{matrix}\right.$; (*c*) a bimolecular or polymolecular salt formed by the union of two or more molecules, $R\left\langle\begin{matrix}CO_2-H_3N\\NH_3-O_2C\end{matrix}\right\rangle R$; (*d*) the ions of the acid group, $R\left\langle\begin{matrix}CO_2^-\\NH_2\end{matrix}\right.$ and H^+; (*e*) the ions of the base, $R\left\langle\begin{matrix}CO_2H\\NH_3^+\end{matrix}\right.$ and OH^-; (*f*) the double, amphoteric ion, $R\left\langle\begin{matrix}CO_2^-\\NH_3^+\end{matrix}\right.$.[2]

The "inner salt" structure was first proposed by Erlenmeyer and Siegel[3] in 1875. Ten years later Ostwald[4] noticed that solutions of glycocoll, $CH_2NH_2CO_2H$, have a very low molecular conductivity and that this is only slightly increased by dilution. He states that in its behavior it is more like a neutral salt than an acid. In 1891 Marckwald[5] called attention to the fact that amino acids of the aliphatic series react only slowly with the mustard oils, while other primary amines react quite readily. Since the amino acids react easily in alkaline solutions, he held that the acids are, in reality, inner salts. Sakurai[6] attempted to substantiate the "inner salt" structure on the preparation from halogen derivatives of the acids and on the resistance which amino acids offer to the formation of acid chlorides. Walker[7] points out that conductivity determinations tell us very little about the structure of glycocoll but that since the conductivity of phenylglycocoll, $C_6H_5NHCH_2CO_2H$, is greater than that of acetic acid it must contain a carboxyl group which ionizes. Tilden and Forster[8] showed that the amino group of amino acids

[2] "Zwitterion."
[3] *Ann.*, *176*, 349 (1875).
[4] *J. prakt. Chem.*, *32*, 369 (1885).
[5] *Ber.*, *24*, 3278 (1891).
[6] *Proc. Chem. Soc.*, *10*, No. 138 (1894).
[7] *Proc. Chem. Soc.*, *10*, No. 139 (1895).
[8] *Chem. News*, *71*, 239 (1895).

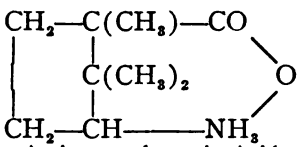
may be replaced by chlorine by the action of nitrosyl chloride and considered this an argument against the inner salt formation. Somewhat later Carrara and Rossi[9] based an argument for the inner salt structure on the conductivity of betaine hydrochloride, $(CH_3)_3NClCH_2CO_2H$. From the values found they considered that the salt was almost completely hydrolyzed to hydrochloric acid and betaine, $(CH_3)_3N\underset{\diagdown\,O\,\diagup}{CH_2}CO$. Winkelblech[10] points out, however, that if betaine hydrochloride is in reality hydrolyzed the conductivity of the solution should be the same as that of the equivalent amount of hydrochloric acid while both Bredig's measurements and those of Carrara and Rossi gave a conductivity scarcely more than one half as great There can be no doubt, of course, that the anhydride of betaine, $(CH_3)_3NCH_2CO_2$, has the structure of a salt, but no one seems to have determined whether this is monomolecular or dimolecular. Our results given below indicate that a solution of an amino acid which gives no inner salt may still contain the acid mostly in the monomolecular form.

Winkleblech[11] discusses the hydrolysis of an amino acid on the basis of conductivity data for weak acids, weak bases and water. It does not seem possible from conductivity data, however, to determine whether the acid is in the form of an inner salt; $R\left<\begin{matrix}CO_2\\NH_3\end{matrix}\right]$, in the unionized state, $R\left<\begin{matrix}CO_2H\\NH_2\end{matrix}\right.$ or $R\left<\begin{matrix}CO_2H\\NH_3OH\end{matrix}\right.$, in the form of the double, amphoteric ion $R\left<\begin{matrix}CO_2^-\\NH_3^+\end{matrix}\right.$ or in the form of a bimolecular salt, $R\left<\begin{matrix}CO_2—NH_3\\NH_3—CO_2\end{matrix}\right>R$. The hydrogen and hydroxyl ions of the amphoteric form would, of course, combine to form water and if the acid and basic functions were of equal "strength" the solution would react neutral. None of these forms would show any conductivity and while the bimolecular form could be distin-

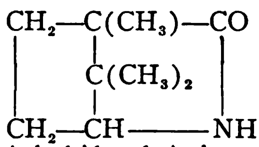
[9] *Atti R. Accad. Lincei* (5), *6*, 208 (1897).
[10] *Z. physik. Chem.*, *36*, 590 (1901).
[11] *Loc. cit.*

guished from the others by a determination of the molecular weight it is not clear how any of the ordinary physical methods could be used to distinguish between the three forms, $R{<}^{CO_2}_{NH_3}$, $R{<}^{CO_2H}_{NH_3OH}$ and $R{<}^{CO_2^-}_{NH_3^+}$. The form $R{<}^{CO_2H}_{NH_2}$ would have a lower molecular weight and might, possibly, be distinguished from the other three by that means. It does not seem to us that the ordinary equations for hydrolysis, which Winkelblech attempts to apply, could be used in a complex case of this sort.

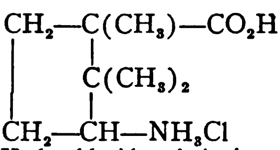
From the above summary it would seem that the evidence with regard to inner salt formation is not altogether satisfactory and light upon the question from an entirely different point of view is welcome. We think that we have secured this from a study of the specific rotations of a series of amino acids derived from camphor. The formulas and names of the compounds are given below. To bring out the relationships more clearly the specific rotations given for the salts are calculated to the basis of one gram of the free acid in 1 c.c. of the solution instead of for one gram of the salt.



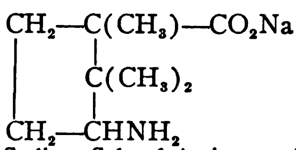
Aminocamphonanic Acid. $(\alpha)_D = -29.2°$.



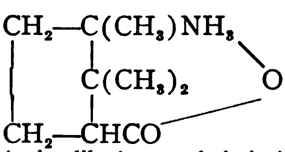
Anhydride of Aminocamphonanic Acid. $(\alpha)_D = -60.5°$.



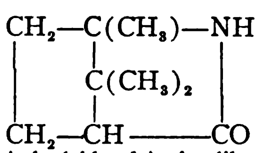
Hydrochloride of Aminocamphonanic Acid. $(\alpha)_D = 25.0°$.



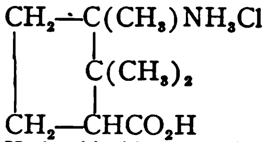
Sodium Salt of Aminocamphonanic Acid. $(\alpha)_D = 52.8°$.

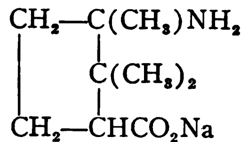


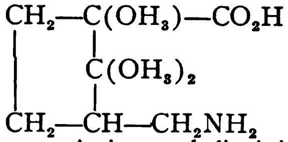
Aminodihydrocampholytic Acid. $(\alpha)_D = 53.7°$.

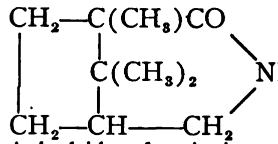


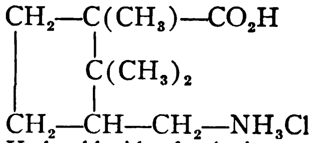
Anhydride of Aminodihydrocampholytic Acid. $(\alpha)_D = 72.8°$.

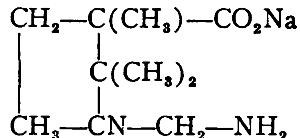

Hydrochloride of Aminodihydrocampholytic Acid.
$(\alpha)_D = 41.3°$.

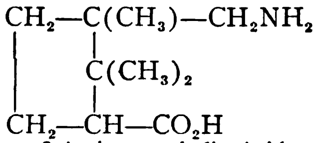

Sodium Salt of Aminodihydrocampholytic Acid.
$(\alpha)_D = 18.3°$.

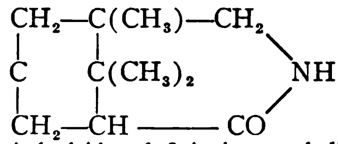

α-Aminocampholic Acid.
$(\alpha)_D = 67°$.

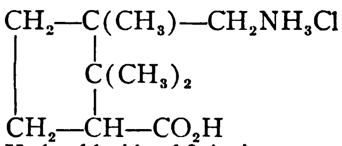

Anhydride of α-Aminocampholic Acid. $(\alpha)_D = -33.9°$.

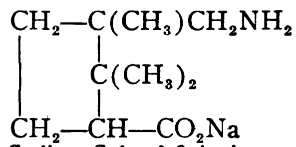

Hydrochloride of α-Aminocampholic Acid. $(\alpha)_D = 44.7°$.


Sodium Salt of α-Aminocampholic Acid. $(\alpha)_D = 62.4°$.


β-Aminocampholic Acid.
$(\alpha)_D = 16.4°$.


Anhydride of β-Aminocampholic Acid. $(\alpha)_D = 66.5°$.


Hydrochloride of β-Aminocampholic Acid. $(\alpha)_D = 41.3°$.

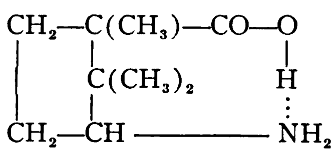

Sodium Salt of β-Aminocampholic Acid. $(\alpha)_D = 14.3°$.

It will be noticed that the aminocamphonanic acid and aminodihydrocampholytic acid are represented as having a cyclic or inner salt structure, while the aminocampholic acids are both represented as having an open structure. The evidence for these structures is based on the specific rotations of the compounds. The rotation of the sodium salt and hydrochloride of aminocamphonanic acid are to the right while that of the anhydride, which is undoubtedly cyclic in

structure, is to the left. The free acid is also left handed, indicating a cyclic structure similar to that of the anhydride. The sodium salt and hydrochloride of aminodihydrocampholytic acid are right handed. The free acid and anhydride are also right handed, but with a considerably increased rotation. The sodium salt and free α-aminocampholic acid are both right handed with rotations closely alike, indicating that each has an open structure, but the anhydride, which certainly has a cyclic structure, is left handed and has a rotation very closely like that of the aminocamphonanic acid, indicating again very clearly that the latter has a cyclic structure and that each *compound contains a cycle of six atoms.* The sodium salt of β-aminocampholic acid and the free acid also correspond closely in rotation, indicating an open structure for both, while the hydrochloride and anhydride have a considerably greater rotation, as is the case with both the free aminodihydrocampholytic acid and its anhydride.

All of these observations are consistent with the hypothesis that aminodihydrocampholytic and aminocamphonanic acid form cyclic salts containing cycles of six atoms, while the aminocampholic acids do not form such salts because, if formed, they would contain cycles of seven atoms. It seems difficult to find any other simple explanation for the observations.

The results also point very strongly to the formula for ammonium salts which represents them as containing quinquivalent nitrogen and against Werner's formula. According to Werner's formula the free aminocamphonanic and aminodihydrocampholytic acids would contain cycles of seven atoms,



Such a formula is quite inconsistent with all that we know about the ease with which rings of five and six atoms are formed and the comparative rarity of seven-atom rings. It is also inconsistent with the close agreement between the rotation of the aminocamphonanic

acid and that of the anhydride of α-aminocampholic acid. We know that the latter compound contains a six-atom ring.

Determinations of the molecular weights in aqueous solutions by the freezing point method have shown that all four of the amino acids are monomolecular in such solutions.

The experimental details of the investigation will be published in the *Journal of the American Chemical Society.*

SOME FURTHER CONSIDERATIONS IN THE DEVELOPMENT OF THE ELECTRON CONCEPTION OF VALENCE.

By K. GEORGE FALK.

(*Read April 24, 1914.*)

The electron conception of valence is based upon the view that when two atoms combine, one becomes charged positively and the other negatively. According to J. J. Thomson,[1] the union of two atoms is brought about by the transfer of a negatively charged corpuscle from one atom to the other; the atom losing the corpuscle becoming charged positively, the one gaining the corpuscle, charged negatively. In order to represent graphically the linkings between atoms the lines or dots which represent the bonds ordinarily are replaced by arrows in the electronic considerations, the head of the arrow indicating the direction in which the corpuscle is assumed to be transferred in the production of the chemical bond.

In every discussion of valence, it is necessary to consider the limitations of the problem. Valence is a number. The valence of an atom shows the number of corpuscles or negative electrons gained or lost by that atom in forming chemical bonds. In slightly different terms, the valence of an atom shows the number of atoms (or groups of atoms) held in combination by that atom when the hydrogen atom as it exists in most of its compounds is taken as the positive unit. Valence may be likened to the capacity factor in energy considerations.[2] Like the capacity factor, it is denoted by a definite number, and while this number may vary under different conditions, a quantity or number of atoms (or combining weights) held by an atom (or combining weight) of the element in question is always meant.

[1] "The Corpuscular Theory of Matter," pp. 138–9 (1907).

[2] Cf. S. L. Bigelow, "Theoretical and Physical Chemistry," p. 80 (1913).

In the same way, the chemical affinity between two combining atoms would correspond to the intensity factor in chemical energy. This chemical affinity can be measured quantitatively only by the change in free energy of the reaction in question. Stability relationships, or chemical affinity discussions, do not enter directly into valence questions, although the existence of substances is controlled entirely by these. The separation of these two problems, valence and chemical affinity, makes it clear that while a great number of substances may be predicted from a consideration of valence structures alone, questions of chemical affinity, or relative stability, limits the number of these substances which are actually known or may be prepared.

As a result of the comparative study of large numbers of compounds, it has become possible to say which would probably exist under ordinary conditions and whether some would react more rapidly than others. These qualitative factors do not give any information concerning the real quantitative measures of relative stability.

Valence is therefore essentially a classifying principle. While it is based directly upon and derived from the atomic theory, it may also be used without considering atoms. The conception of atoms and molecules is based upon the experimental laws of definite and multiple proportions, and if, instead of atoms and molecules, combining and formula weights are used, the same relations will be found, although perhaps not pictured as readily.

The most important feature of the present development is that in speaking of the valence of an element, it is not sufficient to give a number. It is just as important to state whether this number is positive or negative, as the valence or the number of unit atoms or groups held in combination involves also the question whether these are electropositive or electronegative. This is brought out clearly in the Periodic System of Mendeléeff, especially for Groups 4 to 7, where the types of combination with hydrogen and with oxygen represent the maximum negative and positive valences of the elements of these groups.

Since the valence of an atom may be positive or negative depend-

ing upon the loss or gain of corpuscles, the knowledge of the electrical state of an atom in a compound is of importance. Ionization in solution is an invaluable aid in determining the distribution of these charges. Dissolving a substance does not produce electric charges on atoms but only makes these charges manifest to certain experimental methods. These are, in fact, the only direct experimental methods for determining valence. For substances which ordinarily do not ionize, a knowledge of the distribution of the charges is also important. This question was taken up for organic compounds and reactions by Professor J. M. Nelson, of Columbia University and the speaker in a number of papers.[3] It was shown that satisfactory classifications could be developed with the electron conception of valence alone, but that the use of both polar and non-polar valences leads to contradictions in reactions which are fundamentally similar.

With compounds which do not ionize, the Periodic System serves in a general way as a guide for developing valence structures in which relative positive and negative properties of the different atoms are involved. When two atoms are united by a single bond (one unit of valence), where one corpuscle is transferred in the production of the bond, there is ordinarily no question of the direction of transference of this corpuscle, that is to say, which element is positive and which is negative. If isomers exist, the difference in the relative affinity of the atoms for the negative corpuscle may be small (as in iodine monochloride) and the less stable modification may possess the structure in which the corpuscle is transferred in the opposite direction from that of the stable modification.

Some interesting questions are raised when the double bond is considered from the electronic point of view. As used in the past, the justification for the double bond lies in the desire to maintain consistently, constant values for the valence of certain atoms. Practical work during the past fifty years has borne out within certain limits the usefulness of this conception. Before discussing the significance of the double bond with the newer ideas of valence, some general

[3] *Jour. Amer. Chem. Soc.*, *32*, 1167 (1910); *33*, 440 (1911); *35*, 1810 (1913); *36*, 209 (1914).

facts must be mentioned. A single bond between two atoms gives no information as to the stability of the union between these atoms. A double bond between two atoms cannot give any more information with regard to the stability of the linking. Qualitatively it has been found that the rate of reaction for compounds containing double bonds is greater in some ways than the rate for compounds containing single bonds, and that with certain reagents decomposition at the double bond occurs more rapidly than at other parts of the molecule, but this is manifestly different from a discussion of true stabilities of compounds. Reaction velocities bear no simple relation to stabilities of substances and "reactivity" as used in organic chemistry very often refers only to these reaction velocities. The double bond in the ordinary language signifies two units of valences just as the single bond denotes one unit of valence, and in this sense, the only permissible one, the representation of a double bond by two lines is a correct picture of the linking when one line is used for the single bond.

When two atoms of elements which differ very markedly in electrochemical properties are combined by a double bond, one of these atoms may be considered to be electropositive and the other electronegative. In valence terms, an atom of one of these elements has given up two negative electrons to the atom of the other to form the double bond, the former becoming positive, the latter negative. These cases are as simple as those in which only single bonds are involved. Two units of valence are used in each linking with the result that the valence of one of the atoms is $+2$ and of the other -2 due to the double bond.

If two atoms of elements which do not differ much in electrochemical properties are combined by a double bond, the possible relations from the electronic point of view are somewhat more complex. On the other hand, explanations of reactions and classifications of isomers are afforded which are not possible with the view of the double bond in which electrons are not considered.

For the present purpose, it will be sufficient to outline some of the relations. The substances to be considered include mainly the compounds of carbon with double bonds between two carbon atoms

or between one carbon atom and an atom of some other element such as oxygen or nitrogen. In order to illustrate the present discussion with a definite case, a compound containing a double bond between two carbon atoms in which the other bonds are combined with similar groups, may be chosen. Two possible arrangements suggest themselves with regard to the directions in which the corpuscles may be transferred to form the double bond. One carbon atom may lose two corpuscles and the other may gain two in the formation of the double bond. In this case, the valence of the first carbon atom due to the double bond is $+2$, of the second -2. The other possibility involves the gain and loss of one corpuscle by each of the carbon atoms in forming the double bond. In this case, the valence of each carbon atom due to the double bond will be $-1+1$. Since the oxidation of an atom is defined as a decrease of the negative charge or number of corpuscles, and reduction as a decrease of the positive charge, these atoms united by the double bond would be present in different states of oxidation in the different isomeric substances. It is evident therefore, that, with the electron conception, the double bond may show different reactions with various reagents depending upon the directions of the valences of the double bond or the state of oxidation of the atoms united by the double bond. Isomeric substances might exist in which the isomerism would be due to the different directions of the valences of the double bond. This subject has been discussed at some length in previous papers.[4]

Similar relations should be expected to hold with compounds containing a triple bond. While not as much work has been recorded in the literature for substances of this nature, it has been possible, with the electron conception of valence, to explain some reactions of compounds containing triple bonds much more satisfactorily than with the older valence view.

The general view of valence is that of a classification of chemical compounds and reactions. Since the introduction of the electronic nature of valence into all branches of chemistry widens and

[4] Cf. *S. of M. Quarterly*, *30*, 179 (1909); *Jour. Amer. Chem. Soc.*, *32*, 1167 (1910).

extends the classification, and since much of the classification depends upon a number of correlated facts and relations and not upon single crucial and well-defined experiments, it may be expected that some of the formulas advanced and explanations of reactions offered at the present time will be subject to change. Caution must continually be exercised against reading into valence structures ideas which are foreign to valence. A limitation of the questions discussed to the phenomena which may rightly be included would obviate much confusion and bring valence relations into clearer light.

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HEWETTITE, METAHEWETTITE AND PASCOITE, HYDROUS CALCIUM VANADATES.

By W. F. HILLEBRAND, H. E. MERWIN and FRED E. WRIGHT.

Introduction.

(Read April 25, 1914.)

Some years ago, Mr. D. Foster Hewett, in a paper[1] on the remarkable vanadium locality of Minasragra, Peru, described briefly certain oxidation products of the vanadium sulphide ore, patronite, which he was inclined to regard as vanadic acids, although the opinion of one of us (H.), based on preliminary analyses, was that two of the minerals were calcium vanadates.

Several years later the chief constituent of a certain red ore of vanadium from Paradox Valley, Montrose County, Colorado, was identified (H.) as a calcium vanadate, seemingly identical with one of those from Peru. Since then this red ore has been found over a wide area, extending into Utah. A good deal of additional chemical work has been done intermittently during the past three years upon material of both occurrences and it has been studied microscopically. It has developed that, although the minerals are deceptively alike in appearance and general behavior and have the same empirical formula, they seem to be specifically distinct, are probably in fact isomers. The Peruvian mineral, the first known and studied, we are pleased to name *hewettite,* after Mr. D. Foster Hewett, now of the U. S. Geological Survey, who has done so much to make the Minasragra occurrence known. Its isomer may appropriately be called *metahewettite.* It is probable that hewettite occurs also in Paradox Valley (see under metahewettite, pp. 37–38).

The detailed results of the several authors' work are submitted in the following pages, a preliminary announcement having appeared in the *Jour. Washington Acad. of Sci., 3,* 157, 1913.

[1] *Trans. Am. Inst. Min. Eng., 40,* 291, 1909.

HEWETTITE.

Hewettite was rather abundant at the time of Mr. Hewett's visit to Minasragra. It is wholly of superficial occurrence, derived by oxidation from the vanadium sulphide, patronite. The principal specimen examined by us was a lump about the size of a small apple.

In the lumpy aggregates of pure mineral hewettite is deep red (mahogany red)[2] with a somewhat silky luster. Under the microscope the needles measure usually less than 0.01 mm. in width and 0.2 mm. in length. The extinction is parallel. The refractive indices measured by immersion methods could be only approximately found because of the extreme thinness of single blades and the lack of entire parallelism of the blades in a group. Also, β and γ were so high that slight heating was necessary to embed the mineral in the standard refractive media, thus causing expulsion of an unknown amount of water. For Li-light $\alpha = 1.77$, $\beta = 2.18$, $\gamma =$ about 2.35 to 2.4. Elongation is parallel to γ. Pleochroism is strong; γ dark red, α and β very light orange-yellow. The mineral is probably orthorhombic. A determination of density, made by Mr. E. S. Larsen, on air-dried material gave a value 2.618. A subsequent determination by one of the authors (M.), using material containing 9 molecules of water, gave 2.554. The apparent discrepancy between these two determinations is explained by the fact that the material used by Mr. Larsen was partially dehydrated.

The mineral when heated passes through various color changes (see p. 46) and melts readily, forming a dark red liquid; it is slightly soluble in water.

The composition of an almost pure specimen, on which the foregoing optical examination was made, is given under analysis 1 (p. 40). Analysis I*a*, in the footnote on pp. 40–41 (quoted by Mr. Hewett, loc. cit., p. 311), represents a lump of ore showing little evidences of crystallization but otherwise resembling closely the better specimen, although the microscope shows it to be far from homogeneous. In spite of the similarity in appearance of the two specimens, the

[2] The specific color terms used in these descriptions are based on comparisons with Ridgway's standards. See "Color Standards and Color Nomenclature," Robert Ridgway, Washington, D. C., 1912.

analyses show quite different percentages of lime. This is not surprising if we conceive that the vanadium of the patronite has become oxidized to a polybasic acid of quinquivalent vandium, which then was gradually neutralized by calcium. It seems reasonable to expect that ores of all gradations occur from the sulphide patronite to the half neutralized salt hewettite and finally to the fully neutralized salt represented by pascoite (p. 49). Indeed, such intermediate stages are probably represented by a number of the specimens brought from Peru by Mr. Hewett and of which a few analyses are given in his paper. These ores are, for the most part, microcrystalline, though some show distinct evidences of crystallization, as Mr. Hewett pointed out. They are of varying colors, from red through greenish to the black of the original patronite. Some of the specimens are not fully oxidized[3] but contain vanadium in a lower state of oxidation than corresponds to quinquivalency, and even free sulphur. Some of them are characterized by high iron content and relative freedom from lime, as shown by the following analysis,[4] which seems to represent essentially a ferric vanadate.

V_2O_5	57.3
V_2O_4	4.8
MoO_3	3.3
Fe_2O_3	19.6
TiO_2	.1
SiO_2	.6
CaO	.7
H_2O	13.9
	100.3

Molybdenum is naturally a characteristic component of the oxidation products of patronite since it occurs in the patronite ore.

Metahewettite.

Unlike the Peruvian mineral, the North American vanadate is an impregnation in sandstone, generally coating the sandstone grains, sometimes filling cavities and crevices. The specimens are almost

[3] Analysis I indicates that oxidation is not yet quite complete in our best specimen.

[4] Made in 1907 in the laboratory of the U. S. Geological Survey and quoted by Mr. Hewett, *loc. cit.*, p. 311.

always friable, some falling to powder. Gypsum frequently accompanies the metahewettite and often encloses it, producing then the appearance of a distinctly crystallized red mineral. When pure the powder is dark red; gypsum present lightens the color. Even when free from gypsum the red vanadate is almost always associated with other minerals, partly residuals from the impregnated sandstone, although occasionally almost pure material is found, like that represented by analysis II (p. 40). The impurities interfered greatly at first with the precise determination of the composition of the vanadate, particularly as to its water content. For this reason no quantitative analysis of the mineral from Paradox Valley is given, although an abundance of the ore was at our disposal and one or more analyses of it were made before purer material, from Thompson's, in eastern Utah, was obtained. These analyses made evident, however, the chemical identity of the Paradox and Thompson's minerals.

The ore at our disposal from Thompson's differs somewhat from that of Paradox Valley by a greater variation in its shades of red, some of these being very bright in contrast with the usually duller shades of the ore from Paradox.[5] There are also associated with it at least two interesting minerals, both of which were also noticed later in ore from Paradox and the Henry Mountains.

One of these, gray in color, is a hydrous silicate of aluminum, trivalent vanadium and potassium. It is no doubt the same silicate that was first noted by one of us (H.) in carnotite ores and seems to be a constant associate of all the uranium and vanadium ores of western Colorado and eastern Utah, in some places constituting the chief vanadiferous component of the ore. In the ore from Thompson's it forms soft patches throughout the red mass, some of which are of sufficient size to permit of separation in a fairly pure state.[6] Per-

[5] Ores of deep color have been found recently by Mr. Frank L. Hess, of the U. S. Geological Survey, in the Henry Mountains, Utah.

[6] The gray mineral accompanying metahewettite occurs in firm granules consisting of aggregates of very minute doubly refracting particles which cannot be isolated for microscopic study. The refractive indices of aggregates from various portions of the ore varied between 1.59 and 1.64, apparently indicating differences in composition. Some larger lath-shaped particles

haps the greenish tints of some of the Paradox ore specimens are caused by this or another related silicate, like the roscoelite from Placerville, Colorado.[7]

The second characteristic mineral is selenium, in amount up to one per cent. of the ore from Thompson's. It seems to be included as specks in the gray silicate. It is entirely absent from the specimens of Paradox ore first obtained, but is present in ore from the Henry Mountains, Utah, and in some small specimens seen recently that were said to come from Paradox Valley. The presence of selenium can be detected by heating the ore in a glass tube closed at one end, when a red sublimate (sometimes accompanied by a white one of selenium dioxide) appears when most of the water has escaped. The fact that the free element appears as a sublimate does not by itself prove the existence of the selenium in the free state in the ore, for there was enough organic matter present, in a state invisible to the eye, to reduce an oxygenated compound of selenium if present. But the weight of evidence points to its presence in the elemental state and not as a selenide or oxygenated compound.[8] No connection was observed between the presence of the selenium and the bright red color of some specimens of the ore. The differences in shades of red are attributed to differences in physical condition of the metahewettite and to the effect of associated minerals.

were observed, possibly pseudomorphs, containing abundant dark inclusions of more or less prismatic shape arranged parallel to the laths. These laths are aggregates, but portions of them seem to have a definite orientation with respect to the outlines, extinguishing parallel and having γ parallel to their lengths. The inclusions were selenium and bituminous matter. This gray material is probably not roscoelite. For purpose of comparison a study was made of the properties of the roscoelite from Placerville, California, probably identical with that previously analyzed by Hillebrand (*Am. J. Sci.*, *7*, 351, 1899; Bull. U. S. Geol. Survey, No. 167, p. 70, 1900).

Optical properties of roscoelite: Color, deep green with almost metallic luster. 2E variable between 60° and 75° or more. Optical character—. $\gamma = 1.680$–1.685, $\beta = 1.675$–1.680.

[7] Hillebrand and Ransome, *Am. J. Sci.*, *10*, 120, 1900, Bull. U. S. Geol. Survey, No. 262, p. 18, 1905.

[8] The mineral presents deep red transparent prisms, up to 0.05 mm. long, showing parallel extinction. This characterization fits one of the known forms of selenium. Sublimation tests on a few specks indicated free selenium. It seems to be insoluble in carbon bisulphide. Sq far as known this is the first established occurrence of elemental selenium in nature.

Nearly all of our ore specimens from Paradox Valley, Thompson's and the Henry Mountains were free from uranium minerals, but the complexity of the metahewettite ores under special conditions is well illustrated by a very small specimen from Paradox. In addition to constituents indistinguishable to the eye, this showed in juxtaposition and much commingled, metahewettite, carnotite, a brownish material rich in uranium and resembling some forms of ferric phosphate, and jet black, lustrous bituminous or coaly matter. This last, if uraniferous, is perhaps the unnamed mixture of which a preliminary notice by Karl Kithil appeared in *Science, 38*, 625, 1913.

Fortunately several small lumps of very pure material from Thompson's were found. This material gave only a very faint reaction for selenium and was otherwise almost free from contamination. Upon it analysis II. is based.

Metahewettite crystallizing with 9 molecules of water occurs in two typical habits with intermediate forms. The purest material from Thompson's is a feebly lustrous, loose, earthy powder; that from Paradox Valley appears chiefly in compact aggregates of separable, shining blades, though the earthy variety also is found here. Both are deep red, but on account of the larger size of its bright reflecting surfaces the bladed variety appears lighter colored. When powdered the bladed variety is claret brown, the earthy variety is dark maroon. The color of the ores containing the mineral varies greatly because of admixed minerals; furthermore, variation of the water content of the mineral produces changes in color (see p. 46).

Microscopically the earthy variety consists of minute sharply bounded tables about .04 mm. long, piled in subparallel groups. The outlines and optical properties indicate orthorhombic symmetry. The compact variety consists of plates like those in the earthy variety, closely joined in parallel or radiating, more fibrous aggregates. The optical properties are more easily determined on these large aggregates. Pleochroism is strong in groups seen edgewise, but is scarcely noticeable in the plane of the tables. α is light orange-yellow, β deep red, γ deeper red. Two optic axes barely come into the field of a No. 12 objective over a condenser immersed in oil. 2E thus measured is about 135°. The plane of the optic axes is parallel to the

elongation. The refractive indices α and β were determined with difficulty. α was obtained from groups of crystals seen edgewise; β is so high that it could barely be matched without heating by immersion in a mixture of tin iodide, methylene iodide and the compound of arsenic sulphide and methylene iodide. γ could not be obtained except after expelling water from the mineral by heat.

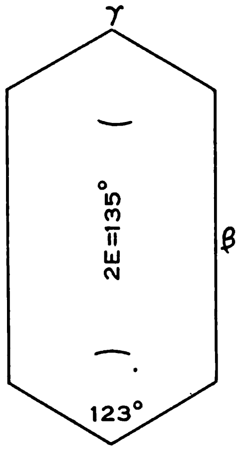


FIG. 1. Optical orientation of metahewettite.

For Li-light $\alpha = 1.70$, $\beta = 2.10$ and 2V (calculated) $= 52°$. α is the acute bisectrix. No measurable differences between the optical properties of specimens from different localities were found. Fig. 1 shows the optical and crystallographic relations. The axial ratio a : b = .54 : 1.

The density of the mineral containing 9 molecules of water—determined in xylol—is 2.511; after the loss of 6 molecules of water it is 2.942. The loss of this water is not accompanied by any perceptible breaking down of crystal structure. The same fact was observed with hewettite. Like hewettite, metahewettite melts readily and is slightly soluble in water. The solubility, slight as it is, affords a means, by the use of much boiling water, of separating from metahewettite the associated minerals mentioned on pages 34 and 35.

Differing strikingly in external aspect from the ores described

above is a single specimen from Paradox Valley, shown us by Mr. Frank L. Hess, of the U. S. Geological Survey. This consists of a single bundle of interwoven fibers implanted on a layer of crystallized gypsum. This specimen, on account of its markedly fibrous structure, bears a closer resemblance to the best of the hewettite from Peru than does the mineral described above. Indeed, optical evidence shows that it is hewettite.

Analyses of Hewettite and Metahewettite, and Their Discussion.

Long after the first analysis of hewettite was made, it was found that both it and metahewettite are extremely sensitive to atmospheric changes in humidity, especially within a certain narrow range. It was therefore essential that they be brought always to the same definite state of saturation with respect to water.[9] It was found by experiment that this condition could be satisfactorily attained by exposing the mineral powder at a definite temperature over sulphuric acid of vapor tension near that of pure water until equilibrium was established. The strength of acid over which the mineral was placed

[9] Failure to observe this precaution may lead to serious error in establishing a probable formula for minerals with variable water content. For instance, if, as with hewettite and metahewettite, the mineral is analyzed in air-dry condition when the air humidity is high, a very different result will be obtained than when the air is dry. The variations in moisture content of these minerals when left exposed to the air may vary 8 or 9 per cent. between September and December in Washington. This is not efflorescence as usually understood, for although the reaction reverses itself with return of humidity the loss of water is not accompanied by breaking down of the crystal structure.

Calcio-carnotite from Colorado (the tyuyamayunite (?) of Nenadkevich) and probably also the original carnotite (essentially the potassium salt) show similar wide differences in water content at different seasons of the year. This may be and probably is true also of other minerals. If so, an explanation is afforded of some of the conflicting statements of different analysts in regard to the water content of certain minerals.

It is, further, important to make a series of exposures over sulphuric acid of increasing concentrations, up to the maximum, at a fixed temperature, and then to carry out tests at rapidly increasing temperatures, in order to detect, by the losses at each step, the number of hydrates that may exist, and also, if possible, what proportion of the water may be differentiated from water of crystallization or of absorption. The curves resulting from such tests with these minerals are shown in Fig. 2.

preparatory to analysis was chosen after a preliminary trial had shown about the range of highest vapor pressure over which little change in water content took place. Sulphuric acid of sp. g. about 1.105 (15°) was found to give the desired vapor pressure, about nine tenths that of saturation.[10] Two different temperatures were employed for establishing equilibrium over this acid in a thermostat, namely, 25° in winter and 35° in summer (temperatures most easily maintained).

At 25° the water-vapor tension of this acid is about 21.8 mm. or 2 mm. less than that of pure water at the same temperature, and 38.8 mm. at 35°, or about 3.5 mm. less than that of pure water. Upon material thus brought to a definite water content the analyses were made. One portion was used for studying the course of dehydration, first by exposing the mineral at 25° (or 35°) until equilibrium was reached, successively over sulphuric acid of concentrations that corresponded to lowering of the vapor tension by tenths approximately and finally over phosphorus pentoxide.[11] With the

[10] The tables of Domke and Bein were used in this connection (*Z. anorg. Chem.*, *43*, 176, 1905).

[11] The value of conclusions deducible from such a series of fractionations on minerals of the kind in question depends on careful observance of certain precautions. In the first place, the mistake must not be made, as in the present case, of using different temperatures for the initial saturation. It was not expected that our tests would extend from winter into summer, as they did at intervals, thus necessitating the use of two temperatures. Of course, the vapor tension of an acid of given strength is markedly greater at 35° than at 25°. The initial water content of the mineral may therefore differ and the results of tests started at the two temperatures not be strictly comparable. For, although the mineral is under a greater water vapor tension of the acid at 35° than at 25° and might therefore perhaps take up more water than at the lower temperature, it is probable that the higher temperature will have its effect on the mineral also but in a quite indeterminate degree (see Fig. 2 and p. 44 of text, for an instructive illustration of one effect of temperature differences, as shown by curves I. and II.). In the second place, at the conclusion of any one test of a series the mineral must not be allowed to cool in the desiccator after removal of the latter from the thermostat, but must be taken out of it at once and inserted quickly into a capped weighing vessel before it has time to cool, for if allowed to cool before removal the final condition will approach that of room temperature and not be that of the experiment. Moisture may be condensed on the mineral and its containing vessel and the former may perhaps reabsorb water in

lower vapor pressures a vacuum was employed. The loss observed at the end of the last exposure was practically identical with that occasioned by a temperature of 100° for a few hours in dry air. Then the fractionation was continued at temperatures above 100°. The results of some of these tests will be given later (pp. 44–45).

The following table of analyses does not show all the determinations that were made. In fact, the first complete analysis of hewettite is omitted, because it was made before the need for bringing the mineral to a definite saturation as to water content was realized. That analysis confirmed, however, in all other essentials than water, the data contained in analysis I. below.

ANALYSES OF HEWETTITE AND METAHEWETTITE.

	Hewettite,[12] Peru, in Equilibrium with Water-vapor Tension of 21.8 mm. at 25°. I.	Matahewettite, Utah, in Equilibrium with Water-vapor Tension of 38.8 mm. at 35°. II.	
V_2O_5	68.19	70.01	
V_2O_4	1.21	——	
V_2O_3	——	.35	
MoO_3	1.56	.13	
CaO	7.38	7.25	7.25
MgO	none	.03	
K_2O	none	.09	
Na_2O	.15	.08	
H_2O (total)	21.33	21.30	(mean of 21.24, 21.31 and 21.34)
Fe_2O_3, etc.	.11	.19	
SiO_2	——	.80 (SiO₂ and Insol.)	
Insol.	.17		
	100.10	100.23	

Trace Li in I., none in II. A very little Cl in I. and II. Trace P_2O_5 and Se in II. No Ba or Sr found in either. V_2O_4 and V_2O_3 assumed, their amounts measured by consumption of permanganate when the mineral was dissolved in dilute sulphuric acid (see discussion of molecular ratios, p. 41).

addition to that condensed on its surface. In the third place, in cases when a vacuum is employed this should be relieved by air bubbling through acid of the same strength and temperature as that in the desiccator, if possible while the latter is still in the thermostat.

[12] An earlier analysis of more compact material from Peru, devoid of crystalline appearance, gave the following results:

Molecular Ratios.

In calculating molecular ratios for the minerals one is confronted with difficulties arising from the presence of vanadium of lower valence than 5, of molybdenum, and of small amounts of constituents other than calcium. These different problems will be taken up in order.

Vanadium.—In hewettite the presence of vanadium in the quadrivalent state may be regarded as probable in view of its existence in many of the specimens representing much less complete oxidation of patronite. In these cases it may be assumed with considerable probability that there exist vanadyl-vanadic oxides or salts, since artificial compounds of the kind are known. If a compound of this nature exists in hewettite, it demands a portion of the V_2O_5, and, if hydrated, a considerable percentage of water.

In metahewettite, however, there is great reason to believe that the vanadium of lower valence is trivalent. That it exists as a constituent of a silicate containing also aluminum and potassium was pointed out on p. 34. It will be so regarded. This stand is taken with full knowledge that a characteristic black ore from Paradox contains much of its vanadium in the quadrivalent state, as mentioned in our preliminary paper.[18]

Molybdenum.—The presence of molybdenum hampers some-

	Ia. Per Cent.	Mol. Ratio,
V_2O_5	66.8	4.79
V_2O_4	.7	
MoO_3	2.8	.26
CaO	4.3	1.00
H_2O (100° —)	13.9	10.03
H_2O (100° +)	6.9	4.97
Fe_2O_3, etc.	3.3	
SiO_2	1.2	
	99.9	

This analysis is given chiefly to show how deceptive the evidence afforded by sharp molecular ratios may be, for microscopical examination showed the material to be very far from pure. It also serves to show what different compositions similar appearing materials may have.

[18] *Jour. Washington Acad. Sci.*, *3*, 158, 1913.

what the drawing of conclusions as to the formulas assignable to the vanadates, since we know nothing positive as to its chemical condition and whether foreign to the vanadate molecule or a part of it, nor, if foreign what part if any of the water is to be assigned to it. So much may, however, be affirmed with positiveness from careful microscopical examination, that the sample of hewettite analyzed represents essentially a single homogeneous mineral and not a mechanical mixture of different minerals. This belief is supported by the behavior of the mineral when it is gradually brought into complete solution by successive treatments with much hot water, for the solution of the molybdenum keeps pace with that of the vanadium. The molybdenum may perhaps best be considered as forming calcium molybdate which is held in solid solution. This assumption has been made because it seems called for by the varying proportions of molybdenum in different specimens and by the difficulty of deducing a probable formula under any other assumption.

Other Constituents.—The absence of any acidic constituent in hewettite to offset the sodium forces us to group this with the calcium as part of the vanadate molecule, unless perchance there be an admixture of a vanadyl-vanadate (see p. 41). In metahewettite the potassium may be referred with a high degree of probability to the silicate of which mention has been made. This silicate requires a small part of the water. There is no evidence of such a silicate in the Peruvian mineral. The sodium and magnesium of metahewettite are not accounted for, but in part at least may belong to the silicate mentioned or to another, except in so far as the chlorine present in small amount may claim some of the sodium (also in hewettite). The amounts reported for sodium may be subject to considerable error in both analyses, and if in error are too high. The iron oxide is no doubt admixed.

After deducting MoO_3 and its equivalent of CaO and neglecting V_2O_4, V_2O_3 and all other minor constituents except Na_2O in I., the molecular ratios deducible with employment of the 1913 atomic weights are:

	I.	II.
V_2O_5	3.06	3.00
CaO	1.00	1.00
H_2O	9.61	9.20

The value for V_2O_5 in I. becomes 3.00 if enough is deducted to form an equi-molecular compound with the V_2O_4.

Before discussing the formulas of the minerals we must present a number of considerations bearing on their specific differentiation, in the course of which certain experimental data essential to a proper understanding of the subject will be given.

Evidences of Specific Distinction of Hewettite and Metahewettite.

The evidence which impels us to give different names to the Peruvian and North American minerals, in spite of the fact that they seem to have the same empirical formula, will now be set forth.

Optical and Crystallographic Differences.—Metahewettite is

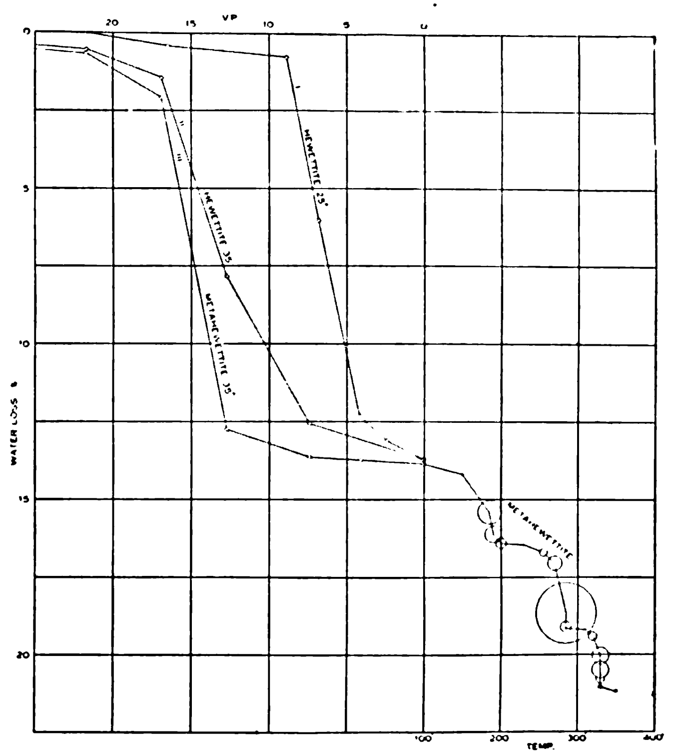


Fig. 2. Showing the course of dehydration of hewettite and metahewettite over sulphuric acid of different concentrations at room temperatures, and of metahewettite at temperatures above 100°.

darker red than hewettite and has two directions of strong absorption for light, while hewettite has only one. Metahewettite crystallizes in well-defined tabular forms or broad blades, hewettite in slender blades.

Loss of Water at Room Temperature.—There is a real difference in the behavior of the two minerals during progressive dehydration over sulphuric acid. Reference to Fig. 2 (curve III.) shows that at 35° metahewettite loses 10.65 per cent. of water in one drop from 17 mm. to 12.7 mm. vapor tension, nearly as much as hewettite loses in the two stages from 17 mm. to 7.4 mm. (curve II.). The points of observation shown in the several curves of the figure in almost all instances represent 24-hour exposures and are approximately equilibrium points. It was unexpectedly found that equilibrium at these points was practically attained in one day, for even after several days' exposure the losses in weight were seldom appreciably greater than after one day. This fact seems to support the argument that the curves indicate a real difference between the two minerals.[14] The curves shown are as a rule quite closely reproducible with different samples of mineral.

The very important effect of varying temperature at a fixed vapor tension of water in the desiccator is strikingly brought out by comparing curves I. and II. for hewettite. It is seen, for instance, that at 35° and 12.7 mm. vapor pressure the mineral loses nearly 8 per cent. of water against a little over half of 1 per cent. at 25° and the same pressure. Again, curve I. shows an equilibrium point at 6.05 per cent. water, curve II. at 7.85 per cent. To the question of why the two points do not appear in the same horizontal line if we are dealing with water of crystallization, two answers suggest themselves: Either (1) an intermediate hydrate which forms at 25° may not have appeared at 35° or, (2) the concentrations of acid used

[14] The lines connecting points of observation in the figure do not signify that the rate of loss was uniform for each unit-lowering of vapor pressure for the interval between two points. The actual loss for each interval would probably be more correctly expressed by a vertical line corresponding to some vapor pressure intermediate between those of the actual points of observation. Just where this line should fall might be determined by making observations with acids of smaller variation of vapor pressures and allowing more time for the attainment of equilibrium.

were not sufficiently close together to indicate all the hydrates formed.

Loss of Water When Heated Above 100°.—Other differences become apparent when the minerals are heated up to the point of losing the last molecule of water. The experiments showing this were made at the geophysical laboratory, the heating being done in an oil or a nitrate bath, both in an open tube and in tubes which were evacuated from time to time, and the loss determined by weighing the tubes.

Metahewettite, after losing 13.8 per cent. (six molecules) of water over strong sulphuric acid, was first heated gradually from 100° up to 350° during one hour with weighings at frequent intervals. Water was expelled abundantly at three stages near the temperatures 185°, 275°, and 340°. The loss at each stage as determined by these weighings and by repeating the heatings and weighings on another sample at favorable temperatures, was found to correspond to about 2.3 per cent., or one molecule of water at each stage[15] (see Fig. 2, lower portion). The sizes of the circles represent the loss of water at each heating divided by the time of the heating. This is the rate of loss of the water.

Hewettite, on the other hand, exhibits only one well-marked loss in weight when heated rapidly. Near 250° a loss corresponding to two molecules of water was observed. Near 300° and 350° there are evidences of increased rate of loss if the temperature is increased rapidly in 30 minutes. These losses correspond to one-half molecule each. These data are not shown in the figures.

[15] This method of rapid heating and frequent weighings affords surer indications of the existence of water in different stoichiometrical proportions than that of holding the mineral in dry air for a long time at successively increasing temperatures. By either method a rate of dehydration, not a condition of equilibrium, is measured. Fig. 2 shows two distinct breaks in the rate of water loss for metahewettite when it is heated rapidly as described in the text. The curves plotted for 5-hour periods of heating in a dry-air current (not shown in the figure) are without distinct breaks.

The temperatures at which water escapes most rapidly bear little relation to those employed in slow heating. Long heating results in a higher loss at a given temperature, and in complete dehydration at a much lower temperature, than very rapid heating.

Change of Color Due to Heating.—Metahewettite, dark maroon in color at first, becomes progressively darker red till the last molecule of water begins to escape, then the color becomes gradually lighter and finally yellow-brown. Concurrent with the last change is a breaking up of each crystal into a crystalline aggregate which retains the form of the original crystal.

Hewettite also darkens when water is lost. At the start, with nine molecules of water, it is mahogany red. The hydrate with three molecules is between carob-brown and liver-brown, the compound with one molecule chestnut-brown, and the anhydrous powder medal-bronze. No breaking down of structure was observed till the last molecule of water was lost.

Changes in Weight and Color after Dehydration.—The powders of both minerals were exposed after complete dehydration to sulphuric acid of sp. g. 1.10. Metahewettite from Utah, after dehydration by heating in air, regained its original weight and color in a few days, but after treatment under greatly reduced pressure the color was not restored, even after moistening, although the observed loss of weight had been the same in both cases. Hewettite, on the other hand, after heating to only 270° and while it still retained one molecule of water, neither regained its original color nor quite its original weight when placed in moist air. In one experiment, after heating to 350° and losing 20.75 per cent. in weight, it regained 19 per cent., but on again fractionating over the acids first used the rate of loss and the amount lost at each step were markedly different from those noted in the first fractionation.

Probable Formula.

Manifestly the empirical formula indicated for metahewettite nearly saturated with water at 35° is $CaO, 3V_2O_5, 9H_2O$. What it may have been when the minerals were originally deposited can not at present be said, although from the curve for water content under varying hygrometric conditions at summer temperatures (Fig. 2), which shows only very slight changes when the humidity is high, it might be argued that the limit of hydration has been reached with nine molecules of water. The effect of low temperatures is,

however, unknown, and it may be that the original water content was higher.

The same statements apply to hewettite, but here the excess of 0.6 molecule of water above nine molecules seems to be real, since it is by no means accounted for by the fraction of one per cent. represented by the nearly horizontal upper part of the curve, which fraction might be considered hygroscopic or absorbed water.[16] It is conceivable that this excess is connected with molybdenum, but much more likely that it has to do with a vanadyl-vanadic compound as already suggested (p. 41).

For the moment we will assume that the formula of both minerals, when holding the maximum amount of water, is CaO, $3V_2O_5$, $9H_2O$. Of what acid, then, are they salts?

The ratio of CaO to V_2O_5 shows that they cannot be salts of orthovanadic acid. Moreover, the known orthovanadates are very few in number and exhibit little stability, but pass readily into hexavanadates. From the fact that six of the nine molecules of water are quickly removable at ordinary temperatures in dry air and the others are much more firmly held, it might seem justifiable to assume six molecules of water of crystallization and three of constitution. Such disposition of them necessitates derivation of the minerals, as quarter-saturated salts, from the hypothetical acid $H_8V_6O_{19}$, an octobasic hexavanadic acid, a possible derivative of orthovanadic acid. We are confronted, however, with the fact that neither such an acid nor salts of it are known. Hexavanadates, however, derived from the tetrabasic acid $H_4V_6O_{17}$, also a derivative of orthovanadic acid, have been described and they resemble in general the two minerals in question, so far as can be determined from the meager data available.

Tetrabasic hexavanadic acid offers the possibility of two isomers of a salt of a bivalent metal. It seems then necessary to consider these minerals as acid salts of this acid, and the name metahewettite for one of them is not only justified but appropriate. If this reference is proper, only one molecule of water of constitution is possible

[16] Not all of the hygroscopic or absorbed water was necessarily removed in the first part of the dehydration over sulphuric acid.

and the other eight are water of crystallization. Against two of the eight being regarded as water of crystallization might be advanced the difficulty of removing the seventh and eighth molecules, but this can not be considered a weighty argument. Neither can the fact that the water content is so markedly affected by outside humidity and is susceptible of repeated removal and restoration be brought as a conclusive argument against the assumption of water of crystallization, for it must be remembered that loss of water is not accompanied by rupture of the crystalline structure, as is usually the case with true hydrates. On the other hand, in favor of water of crystallization, as opposed to water of absorption, must be placed the breaks in the curves of dehydration observed when the minerals are rapidly heated above 100°, and the fact that the content of water at a fixed atmospheric temperature does not bear a continuous relation to the outside humidity.

On the whole we are disposed to adopt the view that eight of the nine molecules represent water of crystallization and to report the formulas of both minerals as examined by us to be $CaH_2V_6O_{17} \cdot 8H_2O$. Under natural conditions mixtures of this and another salt of much lower hydration may and do often occur.

Inspection of the formulas of the artificial alkali and alkaline-earth hexavanadates throws no light on this problem, since the range in number of molecules of water is very wide for the normal alkali salts and the number is reported as 14 for the normal barium salt and 9.5 for the normal magnesium salt. Acid salts of bivalent metals do not seem to have been prepared, unless Ditte's calcium "trivanadate" $CaO,3V_2O_5,12H_2O$, is such a salt, perhaps identical with one of the minerals described by us. Its description, however, does not fit our minerals, since it is reported as very soluble in water and as having the luster of gold. The evidence of the salts mentioned points, however, to the possibility that hewettite and metahewettite may have held more than nine molecules of water when formed, unless the fact that only slight changes occur in their water content with high atmospheric humidity at summer temperatures negatives such a possibility.

Under the name alaite K. A. Nenadkevich has given a very brief

description[17] of a dark red, silky, soft and dense, moss-like mineral to which he assigned the formula V_2O_5,H_2O. The description fits hewettite very well in the main and it will be of interest to learn if on further study alaite may not prove to be a calcium vanadate related to, if not identical with, hewettite or metahewettite. Alaite is one of a number of vanadium and uranium minerals occurring in the Province of Ferghana, Russian Turkestan.

Pascoite.

Not observed in the surface deposit at Minasragra, Peru, but formed on the walls of an exploratory tunnel since its excavation, is a mineral representing a further stage of neutralization by calcium than is shown in hewettite. The specimens examined were among those brought from Peru by Mr. Hewett and the analysis given below was made several years ago in the laboratory of the U. S. Geological Survey. The name proposed, pascoite, is from Pasco, the province in which the locality of occurrence lies.

Crystallographically, this mineral is unsatisfactory, since it occurs only in minute grains and clusters of grains, arranged in a way indicative of a crustaceous deposit—as though they were secondary in origin and had been precipated as a crust about preëxisting masses. No well-developed crystals suitable for goniometric measurement were observed, and only here and there in the crystalline aggregates were minute crystal faces seen. No distinct cleavage was noted, although occasionally indications of an imperfect pinacoidal cleavage were observed in grains under the microscope. The fracture is conchoidal. In color this mineral ranges from dark red-orange to yellow-orange; the more homogeneous masses being uniformly red-orange throughout. In thin flakes it is translucent and the clearer individuals are vitreous to subadamantine in luster, especially on flat crystal faces which glisten here and there in the aggregate. The streak is cadmium-yellow and the hardness about 2.5. The specific gravity is about 2.457, determined in methylene iodide and benezene, on the clearest and most homogeneous material. This value may be slightly low because a crystalline aggregate, instead of a single crystal, was

[17] *Bull. Acad. Sci. St. Petersburg*, p. 185, 1909.

used, and minute air spaces therefore may have been present between the grains.

In the powder form the grains are usually irregular in shape and colored more or less intensely in shades of orange, red, and yellow. Pleochroism is noticeable; $\alpha =$ light cadmium-yellow; $\beta =$ cadmium yellow; $\gamma =$ orange. Absorption $\gamma > \beta > \alpha$. The refractive indices were determined by the immersion method; mixtures of methylene iodide, arsenic tribromide and arsenic sulphide (realgar) being used for the purpose. Owing to the color of the mineral, however, the phenomena on which the refractive index determinations by this method rest were less sharply marked than usual, and the probable error is correspondingly larger.

$$\alpha = 1.775 \pm .005$$
$$\beta = 1.815 \pm .005$$
$$\gamma = 1.825 \pm .005$$

The birefringence is strong and gives rise to high interference colors, even in comparatively thin grains. By direct determination, $\gamma - \alpha$ was found roughly to be about .050. The optic axial angle was measured by the double screw micrometer ocular[18] on sections showing only one axial bar and also on a section normal to the acute bisectrix. For sodium light 2V was found to be $50°.5 \pm 1°$ or 2E is about 100°; for lithium red light 2V is about $56° \pm 3°$, or 2E, about 115°. The determination in lithium light was much less satisfactory and accurate than that in sodium light. The dispersion of the optic axes is very considerable with $2V_{Li} > 2V_{Na}$ and its effect is clearly marked in the interference figure. The appearance of the interference figure shows, moreover, remarkably strong crossed dispersion—so strong in fact that in white light a section normal to the acute bisectrix never extinguishes completely, but near the position of extinction for light of any wave-length shows abnormal interference colors in characteristic tones, especially of green and orange. On a section nearly normal to the acute bisectrix the position of total extinction for sodium light made an angle of about 8° with that for lithium light. This angle, $\gamma_{Li}:\gamma_{Na} = 8°$, is only ap-

[18] *Am. J. Sci.*, *24*, 317–369, 1907.

proximatetly correct, and may be several degrees in error, owing to the weakness of the lithium light source used, and consequent lack of sharpness of position of total extinction.

The above optical data indicate that this mineral is in all probability monoclinic in crystal system, with its optic axial plane normal to the plane of symmetry. To summarize, the determinative optical characteristics of this mineral are: Crystal system, probably monoclinic; axial ratio, unknown; cleavage, poor and probably after 010. H, about 2.5; sp. g., about 2.46. Color, dark red-orange to yellow-orange; luster, vitreous to sub-adamantine. Pleochroism, noticeable, $\gamma =$ orange; $\beta =$ cadmium-yellow; $\alpha =$ light cadmium-yellow. Absorption, $\gamma > \beta > \alpha$. Refractive indices, $\alpha = 1.775 \pm .005$; $\beta = 1.815 \pm .005$; $\gamma = 1.825 \pm .005$.

Birefringence is strong. $2V_{Na} = 50°.5 \pm 1$. $2E_{Na}$ about 100°. $2V_{Li} = 56° \pm 3°$.; $2E_{Li}$ about 115°. Dispersion, crossed and strong, Optical character —. Plane of optic axes normal to plane of symmetry.

On the whole, the material is homogeneous and comparatively free from inclusions and suitable for chemical work. Here and there foreign material was observed, but in the material selected for chemical analysis it was not present in sufficient quantity to veil seriously the chemical relations.

Pascoite melts readily, forming a deep red liquid, and is easily soluble in water.

Analysis of Pascoite.

	Per Cent.	Mol. Ratio.
V_2O_5	64.6	3.18
MoO_3	.3	——
CaO	12.6	2.00
H_2O 100° —	13.8	6.87
H_2O 100° +	7.8	3.88
Undet. and loss	.9	——
	100.0	

The ratios are not as satisfactory as could be desired. The values approach those required from the formula $Ca_2V_6O_{17} \cdot 11H_2O$, which calls for: V_2O_5, 63.76; CaO, 13.10; H_2O, 23.14. Very recent tests show that almost no loss of water occurs at room temperatures until

the surrounding humidity is reduced practically to zero. When dehydrated over P_2O_5 the color is no longer orange but dirty yellow. After rehydration in moist air the color is much brighter yellow, but without any trace of the original orange.

As with hewettite and metahewettite, the amount of water evolved at and below 100° is almost exactly removable by exposure over strong sulphuric acid at room temperature for one or two months and much more rapidly in a vacuum. Above 100° further loss begins, but is complete only at a temperature of perhaps 300°. No experiments have been made as yet to trace the progress of dehydration at temperatures above 100°. Further tests on this mineral are needed and will be made if opportunity offers.

The arguments advanced (pp. 46–48) for hewettite and metahewettite with respect to their chemical classification apply to pascoite also. In this case, if the assumptions made for the former minerals are justified, we have normal calcium hexavanadate with x molecules of water, at least 11 when the mineral was formed.

Analytical Procedure.

The methods of analysis need no special mention except as to the separation and determination of the vanadium and molybdenum. As a rule the portions used for water determinations served also for the other constituents. They were treated in a glass tube, with dry hydrochloric acid gas, after solution in nitric acid and evaporation to dryness in a porcelain boat on a hot plate. The brown vapors were collected in receptacles containing a little water. Two of these in series were sufficient, but a third was sometimes used, all so connected that no back suction of liquid was possible if the gas stream slackened. The material in the boat is attacked instantly the acid vapor reaches it, even without the aid of heat, but the reaction is not complete in one operation even when heat is applied after vigorous action ceases. It is necessary, usually, to remove the boat, to reconvert the contents to nitrates and to repeat the treatment with hydrochloric acid gas several times, and to wash out and dry the glass tube between each operation.

The molybdenum, less volatile than the vanadium, comes off only,

or at least for the most part, during the later periods and upon heating. If present in some quantity it reveals itself by a white crystalline deposit in front of the boat.

The contents of the receptacles and of the tube were finally evaporated in porcelain with sulphuric acid, which was then heated till fumes arose. After dilution, the deep blue solution was transferred to a flask, saturated with hydrogen sulphide gas, and heated while the gas still passed. The flask was then stoppered and allowed to stand, over night as a rule, before filtering. The molybdenum sulphide was roasted to oxide.

The filtrate was brought to boiling in a flask while passing carbon-dioxide gas until hydrogen sulphide was wholly expelled, then titrated in the flask at 70°–80° with permanganate. The vanadium was again reduced, this time with sulphur-dioxide gas, which in turn was expelled by boiling in a current of carbon dioxide, and the vanadium was again titrated. If desired the operations of reduction and titration were repeated. The values obtained after successive repetitions of the reduction by sulphur dioxide agreed well but were always somewhat lower than after reduction by hydrogen sulphide. The difference is no doubt due to the presence in the one case of a little free sulphur from the hydrogen sulphide, which consumes permanganate at the high temperature of titration. If the molybdenum sulphide has been filtered through paper instead of a Gooch crucible, permanganate is also consumed by organic extracts from the paper.

Summary.

Two apparently different calcium vanadates are described, which resemble each other very closely and have the same composition—$CaO \cdot 3V_2O_5 \cdot 9H_2O$—when holding their maximum water content at room temperatures. One of them—hewettite—occurs at Minasragra, Peru, and has been noticed on a single specimen from Paradox Valley, Colorado. The other—metahewettite—occurs at numerous localities in western Colorado and eastern Utah. Both minerals are sparingly soluble in water.

A third calcium vanadate—pascoite ($2CaO \cdot 3V_2O_5 \cdot 11\,?H_2O$)—is also described. This occurs with hewettite at Minasragra. It is very soluble in water.

The first and second minerals are regarded as hydrated acid hexavanadates—$CaH_2V_6O_{17}\cdot 8H_2O$—the third as a normal hexavanadate, $Ca_2V_6O_{17}\cdot 11\,?H_2O$.

The reasons for specific separation of hewettite and metahewettite are set forth in detail. The two minerals are so sensitive to changes in atmospheric humidity that their water content varies within wide limits at different times of the year. The removal of all or nearly all the water does not result in breaking down of the crystal structure, and until this has occurred the water is wholly or in great part taken up again when opportunity is offered.

The importance is emphasized of bringing all minerals that behave in this way to a definite maximum water content before analyzing them and of following carefully the course of dehydration under prescribed conditions. Detailed directions are given for such tests and for avoiding several sources of error.

Attention is also called to two fairly constant associates of metahewettite. One of these (also a constituent of carnotite ores) is a gray hydrous silicate of aluminum, trivalent vanadium, and potassium. The other is elemental selenium, the existence of which as a mineral species seems now for the first time established.

Acknowledgments.

Our thanks are due primarily to Mr. D. Foster Hewett for the material from Peru and to Messrs. T. V. F. Curran, R. H. McMillen and A. G. McNaughton, also to Mr. Frank L. Hess and Dr. W. T. Schaller of the U. S. Geological Survey, for North American material and for valuable information. Dr. Wm. Blum and Mr. E. C. McKelvy, of the Bureau of Standards, were of material assistance in arranging the thermostat and electric furnace used for the water determinations.

Bureau of Standards and Geophysical
Laboratory of the Carnegie Institution,
Washington, D. C., April, 1914.

THE INFLUENCE OF ATMOSPHERIC PRESSURE UPON THE FORCED THERMAL CONVECTION FROM SMALL ELECTRICALLY HEATED PLATINUM WIRES.

By A. E. KENNELLY and H. S. SANBORN.

(*Read April 24, 1914.*)

Object of Enquiry.

This paper describes the process and results of a research made at Harvard University in 1911, to determine the effect of change in atmospheric pressure on forced thermal convection from thin platinum wires. By forced thermal convection is meant the carrying away of heat from the surface of a wire by wind-motion, *i. e.*, by a rapid transverse movement of the wire through the surrounding air. This wind motion through the air dissipates the heat from the wire convectively. The rate of thermal convection depends upon the length and diameter of the wire, its surface condition, the temperature elevation of the wire above the air, the velocity of the motion, and the pressure of the air. The object of the enquiry was to determine the effect of the last-named variable—variation of atmospheric pressure—upon the thermal dissipation, the other quantities being kept constant.

History of the Enquiry.

The research here described was the outcome of an earlier investigation on "The Convection of Heat from Small Copper Wires," by Messrs. A. E. Kennelly, C. A. Wright and J. S. Van Bylevelt, presented at the Frontenac Convention of the American Institute of Electrical Engineers, June 28, 1909, and published at p. 363, Vol. XXVIII., part I., of the *Transactions* for that year. In that research, the forced convection of heat from a thin copper wire, electrically heated to a constant temperature, *i. e.*, maintained at a constant

electric resistance, was discovered to vary as the square root of the wind velocity, which was measured by the speed of the moving wire through otherwise tranquil air. In other words, it was discovered experimentally that in order to dissipate double the power from the wire, at constant resistance and temperature-elevation, it was necessary to quadruple the speed of the wire through the air. This relation was found to hold, within observation errors, for several different sizes of thin copper wire, and for various temperature elevations, between wind-velocities of 2 and 20 meters per second. Below 2 meters per second, the relation deviated towards the case of free convection from a hot wire at rest. That is, at low wind velocities, empirical corrections became necessary for the free convection which naturally occurs from a wire at rest, or moving at zero speed through the air. The possible application of the square-root law of wind cooling to anemometry was also pointed out.

After the results were published in 1909, our attention was drawn to papers by Professor Boussinesq in the *Comptes Rendus* for 1901, Vol. 133, p. 257, and the *Journal de Mathématiques,* 6th Series, Vol. 1, 1905, in which is given the theory of the convection of heat by a stream of liquid from the surface of a cylindrical rod, placed at right angles to the stream. The liquid is assumed to be incompressible and devoid of viscosity. The formula arrived at by Boussinesq, as given by Russell, is:

$$H = 8\theta \sqrt{\frac{s\sigma k V a}{\pi}},$$

where H is the heat carried off convectively per second from unit length of cylinder.

s is the specific heat of the liquid.

σ is the density of the liquid.

k the thermal conductivity of the liquid.

V is the velocity of the liquid.

a the radius of the cylinder.

θ the temperature elevation of the cylinder.

This means that the linear forced convection, or ergs per second per cm. of the cylinder, is proportional to its temperature-elevation above

the liquid, and to the square root of the specific heat, the thermal conductivity, the wind velocity, the fluid density and the wire radius.

Dr. Alexander Russell communicated an important paper on the theory of the subject to the Physical Society of London in July 1910,[1] developing and extending Boussinesq's formula.

Professor J. T. Morris has recently successfully applied the square-root law of forced-convection velocity to the measurement of wind-velocities, using an ingenious form of Wheatstone bridge for this purpose. His observations were communicated to Section G of the British Association in 1912[2] and also to "Engineering"[3] in 1913. His results have confirmed the application of the law for wires of various metals up to diameters of 0.3 mm.

The papers and deductions of Boussinesq were not known to us at the time we presented our former paper in 1909; but since the square-root law of velocity arrived at theoretically by Boussinesq in 1901–1905, for an incompressible non-viscous liquid, has been found to hold within errors of observation for ordinary air, it became desirable to ascertain whether the linear forced convection of air varied as the square root of the air pressure, as suggested by Boussinesq's formula.

Method of Measurement Employed.

The method followed and the apparatus used were respectively the same as those described in the A. I. E. E. paper of 1909, above referred to. A short length of the thin wire to be tested was held in a fork, and was driven by an electric motor at successively varied speeds in a large steel tank, the atmospheric pressure within which was kept constant in each series of tests; but was different in different series.

Test Wire.

The wire used in all of the tests here described was of good commercial platinum, No. 36 B. & S. gauge, with a mean diameter of

[1] *Proc. Physical Society*, 1910, Vol. XXII., also *Phil. Mag.*, October, 1910.

[2] Prof. J. T. Morris, "The Electrical Measurement of Wind Velocity," *The Electrician*, Oct. 4, 1912, pp. 1056–1059.

[3] J. T. Morris, "Distribution of Wind Velocity about a Circular Rod," *Engineering*, Vol. 96, pp. 178–181, Aug. 8, 1913.

0.114 mm. (0.0045 inch). In the tests of 1909, copper wires were used. The advantage of copper is that its resistivity temperature-coefficient is relatively large, and is fairly reliable. On the other hand, hot copper wires oxidize superficially when driven through the air, and are therefore subject to variation in convective dissipation, owing to this change of surface condition. As the test-wire in the new measurements had to be driven inside a steel tank, with only occasional inspections, it was decided to employ platinum, instead of copper; although the resistivity temperature-coefficient of the platinum was but little more than half that of copper; so that the resistance of such a platinum wire is not so sensitive to changes of temperature as a copper wire. Consequently, greater care was needed in the electrical measurements of resistance in the platinum test-wire, in order to determine the temperature elevation.

A measurement of the temperature-coefficient of resistivity of the platinum wire used was made by immersing 5.5 meters of it on a reel in an oil-bath, and measuring the resistance at twelve different temperatures between 0° C. and 100° C. As shown in Fig. 6, the results obtained lie close to the straight line:

$$\rho_t = \rho_0(1 + 0.002575t) \qquad \text{absohm-cm} \quad (1)$$

where ρ_t is the resistivity at t° C. (absohm-cm.), and ρ_0 is the resistivity at 0° C. (absohm-cm.).

The particulars concerning the test wire are given in the accompanying Table:

TABLE I.

Test-Wire Dimensions and Data.

Mean Diameter.		Cross-Sectional Area, sq. cm.	Linear Surface, sq. cm./cm.	Linear Mass, gm./cm.	Linear Res. at 0° C., absohms/cm.	Resistivity at 0° C., absohm-cm.	Temp. Coeff. of Resistivity 0° C.
mm.	Inch.						
0.114	0.0045	1.02×10^{-4}	0.0358	2.415×10^{-3}	1.28×10^{8}	1.306×10^{4}	0.002575

Test-Wire Holder.

The test-wire was held in a fork or frame, mounted on the shaft of the driving motor. The fork is indicated in Fig. 1. It is counterpoised by the sliding weight f. The test-wire is shown at b, held

straight and fairly tight, by the elasticity of the brass strip prongs *aa'*, aided by the tension-screws gg^1. Current is steadily supplied to the test-wire through slip-rings *cc'*, on which rest stationary copper gauze brushes of square cross-section 0.64 cm. (¼ inch) on each

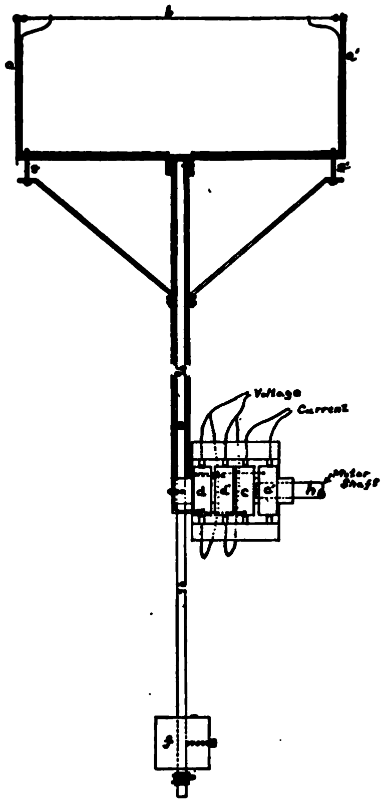


FIG. 1. Details of Rotatable Fork Supporting the Test Wire.

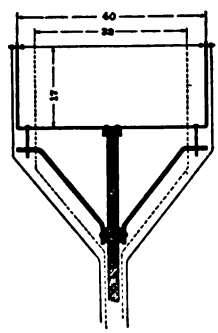


FIG. 2. Details of Fork. Dimensions in Centimeters.

edge. The details of the fork dimensions are shown in Fig. 2. At two points along the test-wire 32 cm. apart, pressure wires are soldered to the test-wire. These pressure wires are of platinum, of the same size as the test-wire. They connect with insulated copper wires fastened to the sides of the fork, and terminate in the slip-rings *dd'* carried by the motor shaft, on which rest two pairs of

stationary gauze brushes. The electrical connections are as shown in Fig. 3. The source of e.m.f. was a storage battery. The regulating resistance *RR* was so adjusted that the ratio of the p.d. between pressure-wires, to the current strength, was equal to a predetermined resistance. That is, the current in the test-wire was gradually increased until the ratio of the reading of the voltmeter *V* to that of the ammeter *A*, was found, by slide-rule, to give the correct resistance sought to be maintained in the test-wire at all wind speeds.

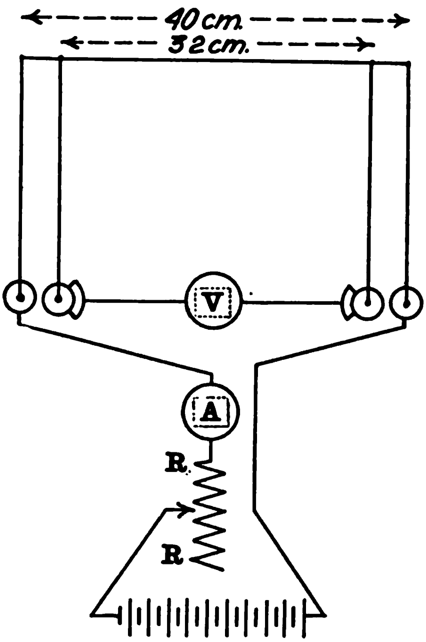


FIG. 3. Diagram of Electrical Connections.

As the driving speed increased, the current supplied to the wire had to be increased, in order to maintain this ratio V/A. When, on the contrary, the driving motor was brought to rest, the current in the test-wire had to be reduced to a relatively small value, in order to reproduce the ratio.

The fork was mounted on the shaft of a ½-HP. 115-volt direct-current shunt motor, arranged to run at adjustable speeds. The

wind speed of the test wire in cm. per sec. was taken as $2\pi \times$ cm. fork radius $\times$ speed of motor in r.p.s. At the other end of the motor-shaft was coupled a small magneto-generator for indicating, by its e.m.f., the speed of rotation. The fork-motor-magneto mechanism is illustrated in Fig. 4, supported on a wooden frame intended to be held in place inside the pressure tank, which is shown with the manhole open.

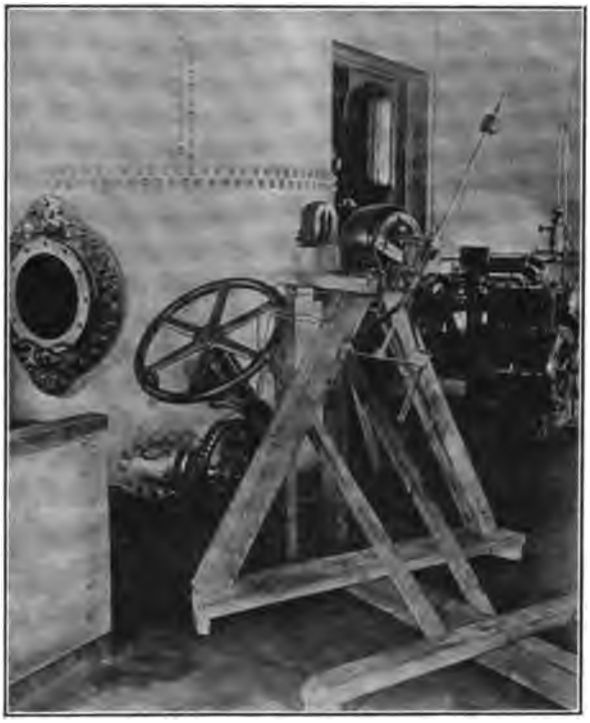


FIG. 4. Photograph of Fork, Driving-Motor, Magneto Speed-Indicator and Pressure Tank.

PRESSURE TANK.

The pressure tank in which the motor and fork were supported was a vertical steel cylinder of ½″ (1.25 cm.) steel plates, riveted. Figure 5 shows the dimensions of the tank, and also the position within it occupied by the motor and fork. The radius of the fork

to the test-wire; *i. e.*, the distance of the test-wire from the motor-shaft axis was 58.5 cm. (23″); and the radius of the pressure tank was 76 cm. (30″), leaving a clearance between the rotating wire and the tank wall of 17.5 cm. (7″). A larger pressure tank, allowing

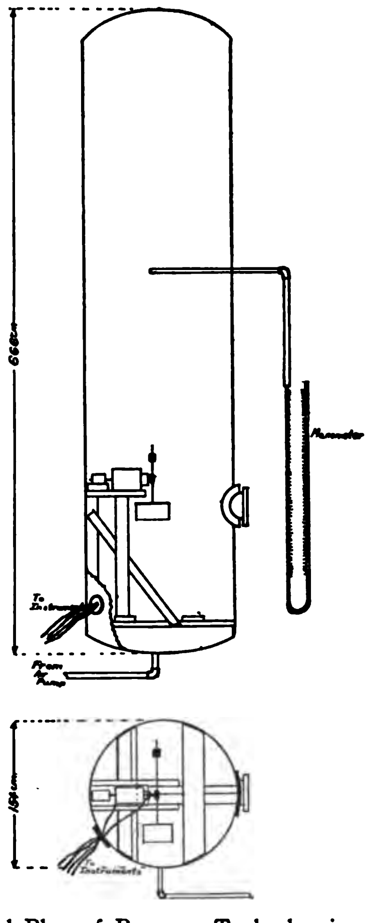


FIG. 5. Elevation and Plan of Pressure Tank showing position occupied by the Test-Wire.

more space and clearance for the revolving test-wire, would have been preferable; but the arrangement was the best that could be made with the apparatus at hand. The results obtained at any

single air-pressure were not so good as those obtained at normal atmospheric pressure in the open air outside the tank, with a larger fork radius, and free air-space. That is, the curves of linear convection against wind-velocity, on logarithm paper, showed more tendency to deviate from a straight line, in these tank tests than in open-room tests, both at low speeds and at high speeds. These deviations might perhaps be explained by air-churnings in the tank, due to the motion of the fork and wire in a somewhat confined space.

The insulated wires leading to motor, magneto, and test-wire, were brought out through holes in a wooden plug bolted air-tight over a manhole.

The speed of rotation of the motor inside the tank was measured in two independent ways; namely (1) by the e.m.f. of the little magneto-generator coupled to the motor, (2) by a contact made

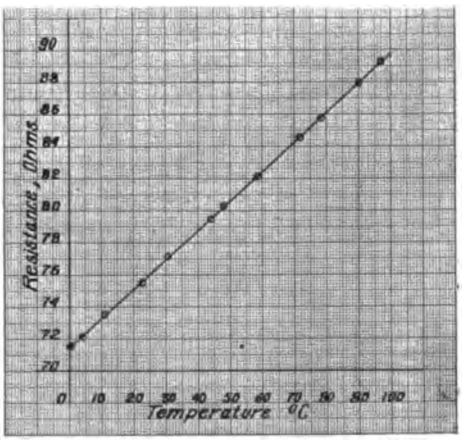


FIG. 6. Resistance in oil of 550 cm. of the Platinum Test Wire at different temperatures between 0° C. and 97° C. in order to determine the resistivity temperature-coefficient.

through a wire on the motor shaft once in each revolution, which gave a click in a telephone. The speed calibration of the magneto and its voltmeter could thus be checked, from time to time, by counting the telephonic clicks in one minute.

The pressure of the air in the tank was controlled by pumps connected with the tank. The tank was fairly tight and ordinarily held its pressure steadily during a test. A large glass U-tube containing mercury was connected with the tank. The difference of level between the mercury in the two arms of the U, corrected for temperature, gave the difference of pressure between the air inside and outside the tank. The absolute pressure of the air in the tank was thus the sum of the U-tube pressure and the corrected barometer pressure outside. This absolute pressure was expressed in "bars" or C.G.S. units (dynes per sq. cm.), by allowing 75.009 cm. of mercury to 1 megabar or 10^6 bars.[4]

Hot-Wire Temperatures.

Two hot resistances were selected for the 32 cm. length of test-wire in different series of tests; namely one at 8.44 ohms, and the other at 10.0 ohms, corresponding to temperatures of 410° C. and 558° C. respectively, by extrapolation from the calibration test between 0° C. and 100° C. indicated in Fig. 6. These temperatures are therefore inferred by resistance. If the temperatures of the wire actually differed from the above inferred values, the values of linear convection here deduced would be correspondingly changed; but the comparative results would be unchanged. So far as the main subjects of enquiry are concerned, it is sufficient that the wire returns to one and the same definite temperature when heated electrically to one and the same resistance. With the air-temperature in the tank in the neighborhood of 20° C., the inferred temperature-elevation of the test-wire by resistance was 390° C. and 538° C. About ten series of speed-measurements were made at each of these elevations, with different air-pressures.

The following table gives one series of tests as an example.

[4] "Les Récents Progrès du Système Métrique," Paris, Gauthier-Villars, 1907, pp. 30–31.

TABLE II.

SERIES OF MEASUREMENTS ON FEBRUARY 16, 1911. Observers A. E. K. and H. S. S. Pressure in tank 75.2 cm. Hg above that in room. Barometer 778 mm. at 14.5° C. Temp. air in tank 18.5° C. Mean absolute pressure in tank 2.04 megabars. Res. of test platinum wire between pressure wires kept at 8.44 ohms. Inferred temp. elevation 391.5° C. R. P. M. of driving motor = 1.14 × magneto voltage.

I. Magneto Volts.	II. Wind Velocity v cm./sec.	III. P. D. on 32 cm. E abvolts.	IV. Current in Wire I abs. amp.	V. Linear Dissipation $P_c = E.I/32$ abwatts/cm.	VI. Linear Dissipation per °C. P_c/θ abwatts / cm. deg. C.	VII. $\frac{P_c}{\theta\sqrt{v}}$.	VIII. $\frac{P_c}{\theta\sqrt{v}+30}$.
		$\times 10^8$		$\times 10^7$	$\times 10^4$		
101	705.5	23.5	0.279	2.051	5.24	1973	1930
126	880.5	24.9	0.295	2.294	5.86	1975	1942
149	1041	26.0	0.308	2.501	6.390	1981	1952
174	1216	26.95	0.320	2.695	6.880	1975	1948
203	1418	27.8	0.330	2.873	7.340	1949	1928
225	1572	28.55	0.339	3.030	7.740	1954	1929
250	1747	29.3	0.348	3.194	8.160	1954	1935
274	1914	30.0	0.356	3.343	8.539	1952	1935
303	2117	30.6	0.363	3.476	8.879	1930	1915
310	2166	30.9	0.367	3.553	9.075	1950	1938
100	699	23.35	0.277	2.023	5.167	1954	1912
74	517	21.75	0.258	1.754	4.480	1970	1916
43	300.4	19.55	0.232	1.420	3.628	2092	1995
0	0	10.5	0.125	0.412	1.050	∞	1917

Column I gives the voltage generated by the magneto on the driving-motor shaft. From these readings, the speed of the test-wire through the air in the tank; or the "wind-velocity" v of Column II is directly derived in cm. per sec. Column III gives, at each steady speed, the P.D. between pressure wires in C.G.S. magnetic absolute units or "abvolts." Column IV gives the corresponding current strength in C.G.S. magnetic absolute units or "absamperes." The ratio E/I is approximately constant at 8.44×10^9 absohms, or 8.44 ohms. Column V gives the linear dissipation of heat from the wire, or the abwatts (ergs per second) per cm. of wire length. Column VI gives this linear dissipation per deg. Cent. of inferred temperature elevation. It will be seen that this varies from 1.05×10^4 abwatts per cm. and ° C. at standstill, up to 9.075×10^4 at 2,166 cm. per sec. Column VII gives the entries of VI divided by, $\sqrt{v}$ giving a value nearly uniform about 1,960, until the velocity v falls to 300 cm. per sec. At standstill, of course, owing

to free convection, the value becomes infinite. If, however, we add 30 cm. per sec. to all the wind velocities v, to correct empirically for free convection as described in the paper of 1909, we obtain the values given in the last column VIII, which do not differ greatly from 1,930 abwatts per cm. ° C. and $\sqrt{v}$, at all speeds in the table.

It will be observed that no correction is made for loss of heat by radiation from the test-wire. That is, the linear dissipations in column VI are treated as though entirely due to convection. In our paper of 1909, a correction was attempted for radiation, on the basis

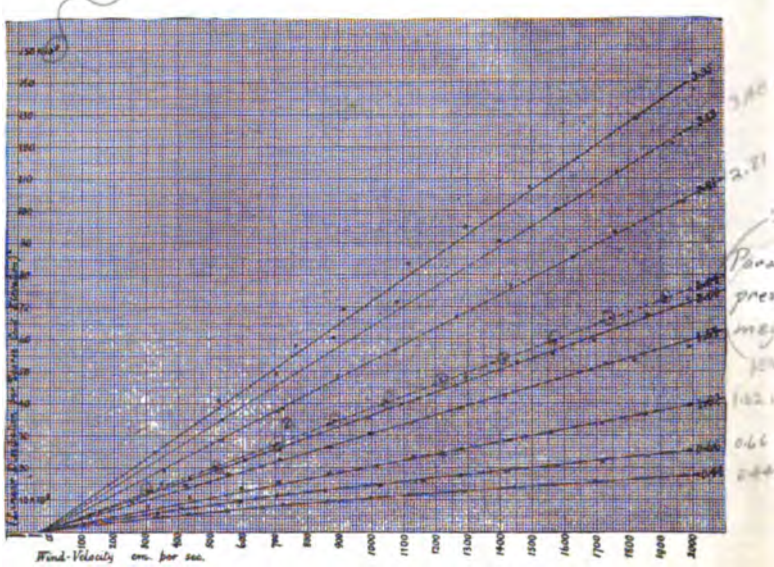


FIG. 7. Curves of $\left(\frac{P}{\theta}\right)^2$ against v, for $\theta = 390°$.

of Stefan's formula. Since, however, it has been pointed out by Dr. Langmuir[5] that the radiation from platinum according to Hagen and Ruben's formula is only a small fraction of that from a "black body," or perfectly non-reflecting radiator, at the same temperature, the radiation corrections in the case of Table II are nearly all less than 1 per cent. of the dissipation, and it has therefore been omitted throughout.

[5] "The Convection and Conduction of Heat in Gases," by Irving Langmuir, *Proc. Am. Inst. El. Engrs.*, June 25, 1912.

The relation found in our 1900 paper was that

$$P_c = k\theta\sqrt{v} \qquad \text{abwatts per cm.} \quad (2)$$

where P_c is the linear convection from the hot wire in abwatts per cm., θ the temperature elevation of the wire, in degrees Centigrade, v the wind-velocity or speed of transverse motion of the wire through the air in cm. per second, and k a constant depending, among other things, on the size and surface-condition of the wire. This formula was found to hold well between the wind velocities $v = 200$ and $v = 2000$ cm./sec. (7.2 and 72 km/hr. or 4.47 and 44.7 statute miles/hr.); but not to hold below $v = 200$, unless 30 cm. per sec. were added as an empirical correction to all speeds to take free convection into approximate account. This empirical correction, applying fairly well, gave:

$$P_c = k\theta\sqrt{v + v_0} \qquad \text{abwatts per cm.} \quad (2a)$$

where v_0 is a virtual velocity of free convection approximating 30 cm. per second.

The relation indicated in (2) can be presented graphically by straight lines on logarithm-paper, but Professor Morris has employed the corresponding relation:

$$\left(\frac{P_c}{\theta}\right)^2 = k^2 v \qquad \left(\frac{\text{abwatts per cm.}}{\text{deg. C.}}\right)^2 \quad (3)$$

That is he plots the square of the observed linear convection per degree C., against the wind velocity, thus producing a straight line, if either (2) or (2a) applies. The procedure is followed in Figs. 7 and 8. Thus, taking Fig. 7, the broken straight line marked 2.04 corresponds to the results in an air-pressure of 2.04 megabars, and the observations in Table I appear on or near this line as small circles. Nine different series are indicated in Fig. 7 at pressures of 0.44, 0.66, 1.02, 1.54, 2.00, 2.04, 2.81, 3.48 and 3.95 megabars respectively, the first two corresponding to vacua, 1.02 to normal atmospheric pressure, and the six others to extra pressure in the tank.

It will be seen that the two lowest curves—vacua—deviate distinctly from straight lines. The remainder are drawn as straight lines, and the observations conform to them fairly well, except at the

two highest pressures 3.48 and 3.95 megabars. This means that equations (2) and (3) held satisfactorily from 1 to 2.8 megabars, but did not hold so well outside those limits of pressure.

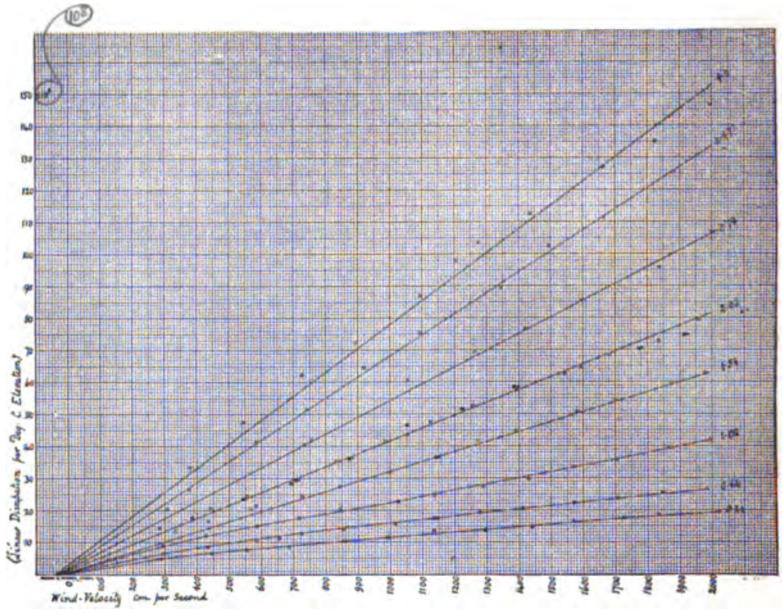
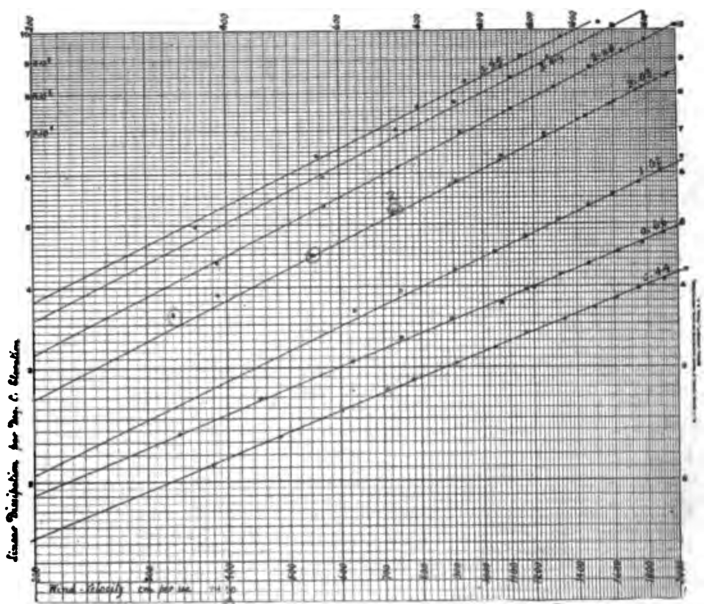


FIG. 8. Curves of $\left(\frac{P}{\theta}\right)^2$ against v, for $\theta = 538°$.

In order to eliminate, as far as possible, any disturbing influence on the forced convection in these tests due to the presence of water-vapor in the air contained in the tank, calcium chloride was kept in the tank. The measurements were all made between January 23 and February 17, 1911, at a time of the year when the air in Cambridge is ordinarily relatively free from moisture. In order to find whether moisture in the air had any considerable effect on the forced convection of heat from the test-wire, one test was repeated at one air-pressure (2 megabars) at each of the two temperature-elevations, first with the air after it had been exposed to the calcium chloride, and second with the calcium chloride removed and a dish of water set over night in its place. The actual difference in the humidity of the air in the tank was not measured, but it was supposed that there

would be a marked difference. It will be seen in Fig. 7 that the small circles on the 2.04 megabar line, representing the dried air test, fairly coincide with the small crosses representing the air test in the presence of water. The same is true for the 2.02 megabar line of Fig. 8. Consequently, the effect of moisture in the heat convection of moving air has not yet been determined from our tests, although it would seem reasonable that in view of the very appreciable known thermal capactiy of aqueous vapor, the effect of moisture might have been apparent.



but checks Fig 7 for v=50 in some cases

Fig. 9. Graphs of $\left(\frac{P}{\theta}\right)$ against v +30 at different pressures for $\theta = 390°$ C. logarithm paper.

It will be seen that the observations in Figs. 7 and 8 indicate a relation:

$$\left(\frac{P_c}{\theta}\right)^2 = k^2(v + v_0) \qquad \left(\frac{\text{abwatts per cm.}}{\text{deg. C.}}\right)^2 \quad (4)$$

where v_0 is a velocity in the neighborhood of 30 cm. per second, which may be assumed as the empirical correction due to free convection

from the test-wire when held stationary in the air. Professor Morris's method of graphic representation has the advantage that it indicates directly the magnitude of the empirical correction v_0. If we take $v_0 = 30$, we have from (4)

$$\frac{P_c}{\theta} = k\sqrt{v + 30} \qquad \frac{\text{abwatts per cm.}}{^\circ\text{C.}} \qquad (5)$$

Figs. 9 and 10 give the graphs of P_c/θ on logarithm-paper, for the various sets of observations. It will be seen the observations lie not far from straight lines. These lines have a gradient of 1 : 2, or correspond to a square-root law, or exponent of 1/2 as in (5); except for the vacua (0.44 and 0.66 megabar), where the gradient is approximately 4 : 10; or would more nearly indicate a relation

$$\frac{P_c}{\theta} = k(v + 30)^{0.4} \qquad \frac{\text{abwatts per cm.}}{^\circ\text{C.}} \qquad (6)$$

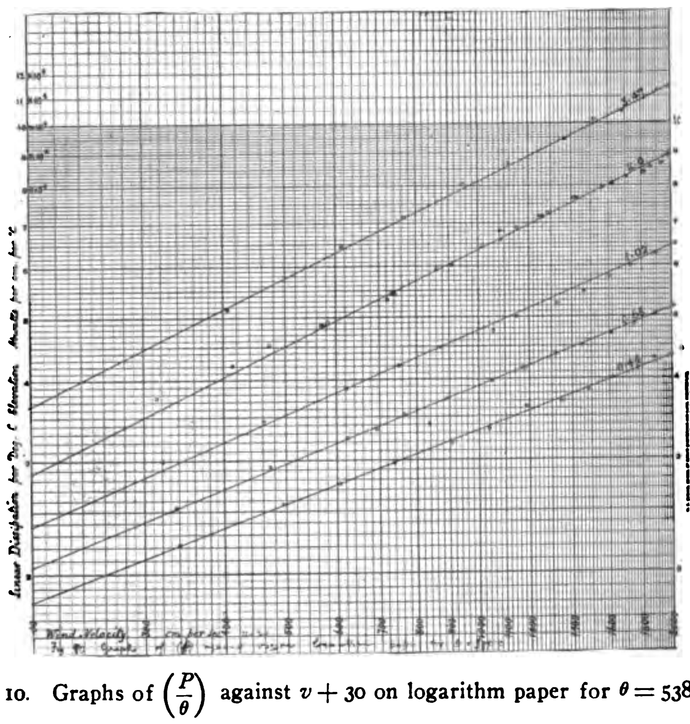


FIG. 10. Graphs of $\left(\frac{P}{\theta}\right)$ against $v + 30$ on logarithm paper for $\theta = 538°$ C.

Considering the results indicated in Figs. 7 and 8, it appears that the slopes of the various straight lines are nearly proportional to the atmospheric pressure. This means that, at least to a first approximation:

$$\left(\frac{P_c}{\theta}\right)^2 = pk'(v + v_0) \qquad \left(\frac{\text{abwatts per cm.}}{\text{deg. C.}}\right)^2 \quad (7)$$

where $pk' = k^2$.
Consequently, when in Professor Morris's diagram, the atmospheric pressure p changes, the ordinates are increased in like proportion. We have then

$$P_c = \theta\sqrt{pk'(v + v_0)} \qquad \frac{\text{abwatts per cm.}}{\text{deg. C.}} \quad (8)$$

so that the linear convection is nearly proportional not only to the square root of the velocity, but also to the square root of the atmospheric pressure. This agrees with Boussinesq's formula (o) when it is remembered that the air-density σ of the medium is proportional to the pressure p. The remaining constant k' involves, among other things, the diameter of the wire. According to Boussinesq's formula (o), the constant k' should be proportional to the square root of the wire diameter. A special investigation should be directed to this question: but the measurements recorded in our earlier paper of 1909 seem to indicate a higher ratio than the square root.

TABLE III.

VALUES OF k' IN THE EXPRESSION $P_c/\theta = \sqrt{k'p(v + v_0)}$ derived from the series of observations at different atmospheric pressures p, at the velocity $(v + v_0) = 1{,}000$ cm. per sec.

$\theta = 390°$.		$\theta = 538°$.	
p Bars.	k'	p Bars.	k'
3.95×10^6	1.87	4.0×10^6	1.98
3.48 "	1.87	3.47 "	1.96
2.81 "	1.85	2.79 "	1.90
2.04 "	1.83	2.02 "	2.00
2.00 "	1.76		
1.54 "	1.915	1.54 "	2.01
1.02 "	1.96	1.02 "	2.16
0.66 "	2.15	0.66 "	2.39
0.44 "	2.14	0.44 "	2.50

Table III shows the value of k' in formulas (7) and (8) for the various series of measurements appearing in this report at the velocity $v = 1{,}000$ cm. per second. It will be seen that k' varies between 1.76 and 2.50, with a mean value near 2.0.

Anemometer Measurements.

A wind-velocity measuring apparatus, or electric anemometer, was constructed of the same thin platinum wire as that used in the preceding tests (0.114 mm. diameter). A length of 25 cm. of this

Fig. 11. Experimental Anemometer.

wire (10 in.) was supported vertically, between insulated clips, in a steel G frame shown in Fig. 11. Pressure taps, of the same size platinum wire, were soldered on to the vertical test-wire, at a distance

of 15 cm. (5.9 in.) apart. The vertical test-wire was then placed at the spot where the wind was to be measured, and heated by electric current. It thus served to measure horizontal wind-velocity in any direction.

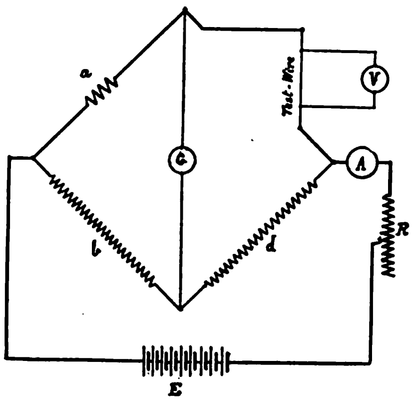


FIG. 12. Connections of Test-Wire for Indirect Measurements of Wind Velocity.

Two methods were used, one indirect-reading, the other direct-reading. In the indirect method, the connections were as shown in Fig. 12. Here the test-wire, shunted by a voltmeter, is placed in a Wheatstone bridge of unequal arms, so that the current in the test-wire side is ten times stronger than in the opposite side *bd*. The bridge is set for balance at a predetermined resistance and temperature of the test-wire. Whatever may be the horizontal velocity of the wind blowing over the test-wire, there is some current strength supplied to the bridge through a meter A, which will restore balance and zero current in the galvanometer G. When this balance is obtained, the readings of the ammeter A, and voltmeter V, are noted. Their product VA; or the voltage square V^2, is proportional to the power dissipated in the 15 cm. of test-wire, from which the velocity of the wind can be deduced with the aid of suitably prepared tables or curves. The advantage of this method is its relatively high precision. Its disadvantages are that it requires to be adjusted for each observation, and in gusty winds, it is not possible to secure a Wheatstone-bridge balance long enough to obtain readings of either V or A.

In the direct-reading method, the connections are as shown in Fig. 13. Here the test-wire is connected across 110-volt lighting mains, through an adjusted resistance, which may consist of incandescent lamps, so as to receive as nearly a constant heating current as is practicable. The voltmeter V is connected to the potential taps, 15 cm. apart on the vertical test-wire. The apparatus is then set up at the place where the wind is to be measured. The four leads are

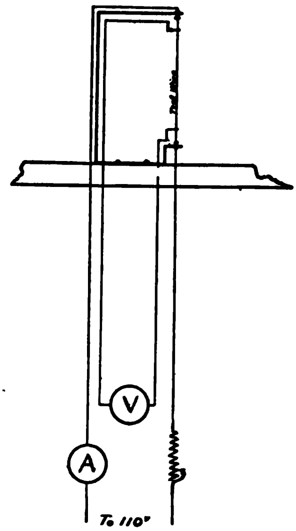


FIG. 13. Connections for Direct-Reading Type of Anemometer.

of any convenient length, and are bound up into a weatherproof cable. From calibration measurements made on a sample of the test-wire in a motor-driven fork, the linear convective dissipation of heat for any safe given linear resistance of the wire is known. As the horizontal component of wind-velocity increases, the temperature of the platinum test-wire falls, since no provision is made in this case to restore the initial temperature. A calibration curve has therefore to be prepared for a given exciting current, whereby the readings of the voltmeter, which may be a recording instrument, become convertible into wind-velocities. A set of calibration curves is given in Fig. 14 to the left-hand scale, both for 1.5 amperes and 2.0 amperes, constantly sup-

plied to the test-wire from the 110-volt circuit. It will be seen that when the wire is greatly cooled by the wind, a very appreciable correction for the temperature of the wind enters into the result; although at a temperature elevation of say 300° C, this correction would be comparatively small. It is necessary to set the current at such a value that when the wind fails, the test-wire shall not be dangerously heated. It was found that with a platinum test-wire of 0.114 mm. diameter, as used in these measurements, 1.5 amperes was a suitable current for wind-velocities up to 15 km. per hour. Thus, as indicated in Fig. 14, with a wind of 10 km. per hour, and a temperature of 10° C., the voltmeter reading was 4.3 volts. When, however, the wind-velocities were higher, the current was increased to 2 amperes, which, in still air, raised the wire temperature to visible redness. At 30 km. per hour, and 10° C. wind temperature, the p.d. on 15 cm. was then 5.8 volts.

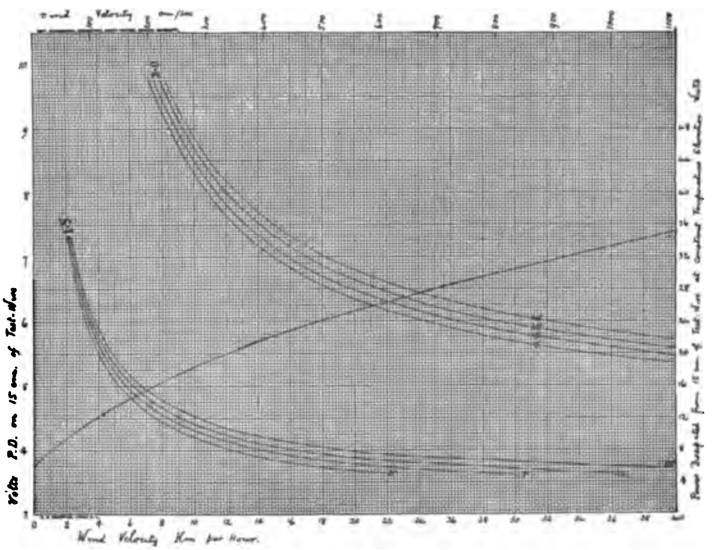


FIG. 14. Calibration Curves of 15° cm. Test Wire.

The *G*-support and test-wire were fastened to a pole and supported out of doors, exposed to the weather for some weeks. The apparatus appeared to be durable, and constant in its indications throughout that time, except that the solderings of the platinum tap-

wires across the test-wire, introduced an element of weakness. After exposure of some days, the test-wire was apt to break at a soldered point. In subsequent out-door trials, therefore, the tap-wires were simply twisted on to the test-wire. These tap-points involve a certain small error due to their cooling effect on the test-wire. It is, therefore, desirable to make the tap-wire as thin as is practicable, in view of both mechanical strength and electric resistance.

In a wind, the readings of the voltmeter anemometer are always fluctuating; but a mean value at any moment can always be estimated. A heavily damped voltmeter may conveniently be used.

The rising parabolic curve in Fig. 14 indicates, to the right-hand scale, the watts convected from 15 cm. of the same test-wire at different wind-velocities up to 1,100 cm./sec. or 40 km./hr. with constant resistance maintained in the wire; *i. e.*, by the method of Fig. 12. It is evident that for high wind-velocities, the indirect method of constant test-wire temperature is more sensitive than the direct-reading method of constant current. For lower velocities, however, the direct-reading method is much the more convenient, but requires to be corrected for the wind-temperature.

In the use of the constant-current direct-reading method, tungsten lamps have an advantage for the regulating resistance of Fig. 13 in that they tend to compensate for changes in the resistance of the test-wire at different wind-velocities; or to act as ballast resistance for the closer maintenance of constant current.

Conclusions.

1. The forced convection of heat from a thin platinum wire at constant temperature moved transversely through the air, varies not only approximately as the square root of the speed, but also approximately as the square root of the air-pressure (or air-density), in accordance with Boussinesq's formula.

2. At air-pressures below half an atmosphere, the above square-root relation was sensibly departed from. At pressures above 3 atmospheres, the relation was also departed from. Although the departures in both cases exceed the limits of observation errors, it is not certain whether they may have been due to imperfections in the

apparatus, such as eddy-currents in the confined air, caused by air-churning in the pressure-tank. In other words, it is uncertain whether, if a more spacious pressure-tank could have been used, with a longer fork radius, the square-root relation might not have held better than it did at the upper and lower air-pressures.

3. The effect of moisture in the air, upon the forced convection of heat from a thin wire, seems to be small, and has not yet been determined.

4. The forced convection of heat from a thin wire at constant temperature in air of variable pressure may be regarded as varying approximately with the square root of the mass of air displaced by the wire per second, or as $\sqrt{v\sigma}$, where v is the wind-velocity of displacement and σ the density of the air.

5. When the air-pressure p remains constant, $(P_c/\theta)^2$ or the square of the linear convection per deg. C. elevation, plotted against wind-velocity v, gives a straight line for a thin metallic wire. When, however, the air-pressure p varies, then it seems that, at least to a first approximation, $(P_c/\theta)^2/p$ plotted against wind-velocity v, gives one and the same straight line, for that wire, for all values of p from 0.5 to 2.0 megabars.

6. A thin vertical platinum wire about 25 cm. long, after being calibrated in a motor-driven fork, can serve as a recording wind measurer or anemometer. The record requires to be corrected both for the temperature and pressure of the air. The degree of precision obtainable is greatest at low wind-velocities.

THE UNITED STATES AS A FACTOR IN WORLD POLITICS.

By L. S. ROWE, Ph.D., LL.D.

(Read April 24, 1914.)

There is probably no characteristic of American political life that has made a deeper impression on foreign students of our institutions than the fact that while all matters of domestic policy are subjected to the most searching analysis, questions of foreign policy do not in normal times become the topic of public discussion. It is not until our international relations have reached a critical stage that real public interest is aroused. In most cases, however, before public opinion has become crystallized, the national executive has committed the country to a certain line of action. Thereafter the country's policy is determined by the logic of events rather than by the dictates of public opinion.

In comparing the French, German and British magazines and newspapers with those of the United States, one is impressed with the fact that while the European journals are constantly discussing questions of foreign policy, little or no attention is given to this subject in our American journals until some problem has reached so critical a stage that it imperils the peace and safety of the country. The causes of this contrast are to be found not in the more serious character of foreign journals, but in the fact that the American people have been accustomed to confine their thinking on public affairs to questions of domestic policy.

Under our system of government this attitude involves a real danger because it removes our foreign relations from the control of public opinion, and makes them dependent upon the personal views of the President of the United States, subject to such influences as may, for the time being, be dominant in Washington. When public opinion does assert itself, such assertion usually comes as the result of a wave of popular feeling, obeying an emotional impulse. The

root of the difficulty is that the national thought of the people of the United States has failed to keep pace with the changes in the international position of the country. The early policy of our country, as well as our national thinking during the infancy of the republic, was concentrated on the idea of national isolation—freedom from entangling alliances with European countries, and the separation of American from European interests. National thought has remained in this stage of development whereas national power and national influence have long advanced beyond these narrow confines. We have attained the dignity of a world power, but our national thought has not advanced to a consciousness of the responsibilities which this position involves. The great problem now confronting the country is to bring about closer harmony between these two factors.

We are at the present moment witnessing one of the most serious consequences of this lack of adjustment which is affecting the international position and influence of the United States to a degree which cannot help but arouse the grave concern of every thoughtful and patriotic citizen. In a brief period of fifteen years we seem to have sacrificed the position of leadership in the maintenance of world peace, and have become one of the disturbing factors in international affairs. How is it, it will be asked, that a nation which through the contributions of more than a century has gained an enviable position as a leader in the great movement for the advancement of international goodwill, should within so short a space of time sacrifice this enviable position and come to be looked upon by all nations of western civilization as an uncertain factor in the orderly development of international relations.

Every student of international law and of world politics has been deeply impressed by the important part played by the United States in placing the conduct of international relations on a distinctly higher plane. It seems, at first glance, extraordinary that during the first half century of its existence a nation so weak and in many respects so unorganized should have been able to exert so important an influence on international law. When, however, we stop to reflect that during the first decades of the nineteenth century the United States held the balance of power amongst the nations of western civilization, the apparent paradox is readily explained.

The farseeing statesmanship of the founders of the republic led to the adoption, as a cardinal principle of American foreign policy, that the United States must be kept free not merely from entangling European alliances, but from any participation in the conflicts then raging in Europe. This principle of aloofness from European entanglements led to the assertion of those principles of American neutrality which, while serving primarily the interests of our national integrity, accomplished the still larger purpose of laying the foundations for the modern law of neutrality. In performing this service the United States contributed toward eliminating some of the most fruitful causes of international irritation, thereby promoting the interests of world peace.

It has been the laudable ambition of successive secretaries of state to continue and to strengthen those traditions which gave to the country a position of such unique power amongst the nations of both eastern and western civilization. In spite of these efforts, however, there is noticeable during recent years a distinct falling off in our international prestige. Little by little, the confidence of the peoples of Europe and of the American Continent has been undermined until to-day we find ourselves in a situation which possesses none of the elements of that splendid isolation which so long characterized the position of Great Britain and which, if not remedied, is likely to deprive us of the possibility of carrying to a successful conclusion a mission which constitutes the chief glory of American foreign policy during the first century of our national existence. It is, therefore, a matter of real national moment to inquire into the causes which have brought about this change, and to seek a remedy if such exists.

Of the elements contributing to the present situation, some are of long standing, the cumulative effects of which are now being felt, while others are of comparatively recent development. Amidst the splendid record of achievement during the first century of our national existence there looms up one aspect of our policy which has been a cause of deep concern to successive presidents and to successive secretaries of state. I refer to the inadequacy of our national legislation for the protection of resident aliens. A long

series of massacres, beginning with the Chinese massacre at Rock Springs, Wyoming, in 1895 and ending with the lynching of Italians in 1899, 1901 and 1910, have placed our national government in the humiliating position of acknowledging to foreign powers that although the sole responsibility for the conduct of our foreign relations rests with the federal authorities, they lack the power to fulfill the most fundamental of international obligations—the duty to bring to justice the persons responsible for such crimes. The matter was referred to as early as 1899 by President McKinley, who, in his annual message of December 5th, said:

"For the fourth time in the present decade a question has arisen with the government of Italy in regard to the lynching of Italian subjects. The latest of these deplorable events occurred at Tallulah, Louisiana, whereby five unfortunates of Italian origin were taken from jail and hanged. . . . The recurrence of these distressing manifestations of blind mob fury directed at dependents or natives of a foreign country suggests that the contingency has arisen for action by Congress in the direction of conferring upon the Federal courts jurisdiction in this class of international cases where the ultimate responsibility of the Federal Government may be involved."

The matter was again vigorously taken up by President Roosevelt in his message of December, 1906, in which he said in referring to the difficulties that had arisen because of educational discrimination against the Japanese in California:

"One of the great embarrassments attending the performance of our international obligations is the fact that the statutes of the United States are entirely inadequate. They fail to give to the national government sufficiently ample power, through United States courts, and by the use of the army and navy, to protect aliens in the rights secured to them under solemn treaties which are the law of the land. I, therefore, earnestly recommend, that the criminal and civil statutes of the United States be so amended and added to as to enable the president, acting for the United States government, which is responsible in our international relations, to enforce the rights of aliens under treaties. There should be no particle of doubt as to the power of the national government completely to perform and enforce its own obligations to other nations. The mob of a single city may at any time perform acts of lawless violence against some class of foreigners which would plunge us into a war. That city by itself would be powerless to make defense against the foreign power thus assaulted, and if independent of this government it would never venture to perform or permit the performance of the acts complained of. The entire power and the whole duty to protect the offending city or the offending community lie in the hands of the United States government. It is unthinkable that we should continue a policy under which a given locality may be

allowed to commit a crime against a friendly nation, and the United States government limited, not to preventing the commission of the crime, but, in the last resort, to defending the people who have committed it against the consequences of their own wrong doing."

In 1909, in his inaugural address, President Taft emphasized this serious defect in the conduct of our foreign relations, in the following words:

"By proper legislation we may, and ought to place in the hands of the federal executive the means of enforcing the treaty rights of such aliens in the courts of the federal government. It puts our government in a pusillanimous position to make definite engagements to protect aliens, and then to excuse the failure to perform those engagements by an explanation that the duty to keep them is in states or cities, not within our control. If we would promise we must put ourselves in a position to perform our promise. We cannot permit the possible failure of justice, due to local prejudice in any state or municipal government, to expose us to the risk of a war, which might be avoided if federal jurisdiction was asserted by suitable legislation by Congress and carried out by proper proceedings instituted by the executive in the courts of the national government."

It is clear that no nation can shirk the responsibilities of its international obligations without arousing widespread opposition. The constitutional authority granted to our federal government is sufficiently comprehensive to include all powers necessary to meet our international obligations. We cannot permit our states, which occupy no international status, to plunge us into irritating controversies with foreign countries. The dignity of the national government and the demands of national self-respect require that the federal executive be given statutory powers sufficiently broad and that the federal judiciary be given jurisdictional authority sufficiently comprehensive to enable the national government to do its full duty in the protection of the person and property of aliens resident within our borders. The first step in this direction is the enactment of a law giving to the federal courts jurisdiction over all cases in which the treaty rights of a citizen or subject of a foreign country are involved. A bill to this effect has been before the Congress of the United States on several different occasions. Its precise text is as follows:

"Be it enacted by the Senate and House of Representatives of the United States of America, in Congress assembled, that any act committed in any state or territory of the United States in violation of the rights of a citizen

or subject of a foreign country secured to such citizen or subject by treaty between the United States and such foreign country, which act constitutes a crime under the laws of such state or territory, shall constitute a like crime against the peace and dignity of the United States, punishable in like manner as in the courts of said state or territory, and within the period limited by the laws of such state or territory, and may be prosecuted in the courts of the United States, and upon conviction, the sentence executed in like manner as sentences upon convictions for crimes under the laws of the United States."

That the federal government has ample power to enact such legislation has been repeatedly affirmed by the Supreme Court of the United States. In Baldwin *vs.* Frank (120 U. S. 678) one of the leading cases on the subject, the question involved was whether the Civil Rights Acts were applicable to a conspiracy to deprive Chinese subjects, residing within a state, of rights secured to them by treaty. In the course of its opinion the court said:

"The precise question we have to determine is not whether Congress has the constitutional authority to provide for the punishment of such an offense as that with which Baldwin is charged, but whether it has so done.

"That the treaty-making power has been surrendered by the states and given to the United States is unquestionable. It is true also that the treaties made by the United States and in force are part of the supreme law of the land, and that they are as binding within the territorial limits of the states as they are elsewhere throughout the dominion of the United States.

"That the United States have power under the Constitution to provide for the punishment of those who are guilty of depriving Chinese subjects of any of the rights, privileges, immunities or exemptions guaranteed to them by this Treaty, we do not doubt. What we have to decide, under the questions certified here from the court below, is whether this has been done by the sections of the Revised Statutes specially referred to."

Again, in the Debs case (158 U. S. 564) the Court held:

"The entire strength of the nation may be used to enforce in any part of the land the full and free exercise of all national powers and the security of all rights entrusted by the Constitution to its care. . . . If the emergency arises, the army of the nation, and all its militia, are at the service of the nation to compel obedience to its laws."

All this tends to prove not only that we have been remiss in the performance of our international obligations, but that such remissness has not been due to any defect in our national Constitution but to the failure of Congress to extend the jurisdiction of the federal courts and to grant specific authority to the federal executive to

fulfill manifest international obligations. Indeed, it would seem from the decision in the Debs case that even without specific statutory authority, the national executive may do far more than has hitherto been done in maintaining the supremacy of the federal treaty making power.

The failure of Congress to make adequate provision for the protection of resident aliens has aroused resentment not only in the states whose *nationals* have suffered most severely, but has seriously injured our reputation for fair dealing throughout the civilized world. The remedy for this situation is so simple that there is no excuse for further delay in making it effective.

A second influence which has played an important part in estranging the goodwill of foreign countries is the widespread belief that there exists in the Congress of the United States a tendency to force upon the executive a narrow and technical interpretation of treaties. Secretary Hay once said of certain senators who attempted to defeat every treaty presented to the Senate, that their idea of a treaty was a document which gained everything for the United States and gave nothing to the other party. The ruthless way in which the Congress of the United States has at times swept aside treaty obligations, and the unwillingness to bring national legislative policy into harmony with our international obligations, have created the impression that the promises of the United States cannot be depended upon, and that even the best intentions of the President and his advisers are apt to be thwarted by the action of Congress.

The culminating point of a series of instances was reached in the provision of the Panama Canal Act exempting American coastwise shipping from the payment of canal tolls. Whatever may be our opinion as to the desirability of the exemption clause viewed as a question of domestic policy, it is clear from the history of the Clayton-Bulwer and of the Hay-Pauncefote treaties and from the testimony of those who assisted in their negotiation that the United States made no attempt to reserve to itself the right to give preferential treatment to its own merchant vessels. The privileges acquired by the United States under the Hay-Pauncefote Treaty involved certain concessions on the part of Great Britain, for which she ex-

acted the observance of the principle of equality of treatment. It would be a reflection on our country's reputation for fair dealing if, after securing the abrogation of the Clayton-Bulwer Treaty, we were to repudiate the concessions, the making of which rendered possible the ratification of the Hay-Pauncefote Treaty.

It is fortunate for the world's peace that there is rapidly developing a body of international opinion to which the policy and conduct of individual nations must conform. Violations of the standards set by this opinion place the offending nations under the ban of international disapproval. With each year the commercial and social relations between nations are becoming closer. This increasing interdependence means that national policy must be made subservient to international right and to international obligation. No nation is a law unto itself, and it is evident that even our concept of national sovereignty must be subjected to revision in order to conform more closely to those larger principles of international reciprocity and fair dealing, upon which the maintenance of western civilization so largely depends. Just as competition has gradually given way to coöperation in the industrial world, so in international affairs the concerted action of states and the idea of mutual obligation as between states are gradually taking the place of the more primitive principle that every nation may formulate its national policy on the basis of national interests regardless of the higher standards of conduct now prevailing in the society of states.

Fortunately, for the good name of the United States, the President has courageously taken a position which has not only aroused the admiration of the civilized world but has placed our country under a debt of obligation. In his address of March 5, 1914, to the Congress of the United States he sounded a note which served to impress upon the nation the sacredness of treaty obligations. Speaking of the Hay-Pauncefote Treaty he said:

"We consented to the treaty; its language we accepted, if we did not originate it; and we are too big, too powerful, too self-respecting a nation to interpret with a too-strained or refined reading the words of our own promises just because we have power enough to give us leave to read them as we please. The large thing to do is the only thing we can afford to do, a voluntary withdrawal from a position everywhere questioned and mis-

understood. We ought to reverse our action without raising the question whether we were right or wrong and so once more deserve our reputation for generosity and for the redemption of every obligation without quibble or hesitation."

The magnitude of the President's service goes far beyond the vindication of the Hay-Pauncefote Treaty. These words and the determination which lies back of them place the international relations of the United States on a distinctly higher plane, and, if properly supported by the united opinion of the country, will do much toward regaining for the United States the enviable position which we once occupied. All secondary and party interests must be made to bow before that higher standard of international dealing which the President so vigorously champions.

A third influence which has played an important part in arousing opposition to the United States has been the tendency to permit new doctrines of American foreign policy to masquerade under the cloak of the Monroe Doctrine. In the adjustment of our relations with Mexico, with the islands of the West Indies, and with the countries of Central America, we have fallen into the error of endeavoring to build up our relations on the basis of the negative principles formulated in 1823. Instead of clearly and definitely facing the fact that these sections of the American continent occupy an exceptional relation toward the United States, and building up our policy on the basis of this exceptional relationship, we have formulated vague principles purporting to be based on the Monroe Doctrine which have aroused the suspicion, the distrust, and even the hostility of the most progressive countries of South America. We should clearly and definitely recognize the fact that everything that affects the progress, the stability and the well-being of the islands of the West Indies, of Mexico and of Central America, is a matter of immediate and direct concern to the United States. It is a concern different in kind from that which affects our relations with the countries of South America. The acquisition of Porto Rico and our exceptional relations with Cuba, have made of the United States a West Indian power. The construction of the Panama Canal and the acquisition of the Canal Zone have made of the United States a Central-American power, and finally, the fact that Mexico is our

neighbor, that large bodies of American citizens have taken up residence there, and that vast American interests amounting to over a billion dollars, are invested in Mexican enterprises—all these factors indicate the necessity of developing a policy toward these three sections of the American continent based on the positive national interests involved rather than on the negative principles of the Monroe Doctrine. We should frankly proclaim to the world that basic national interests demand that these sections of the American continent shall not only remain free from European complications, but that the primary requisites for the preservation of civilization shall be maintained. Continued disorder, the disregard of fundamental human rights, the undermining of respect for property—all these constitute elements which vitally affect the well-being and safety of the United States. This does not mean either the extension of a proctectorate or an unwarranted interference with the domestic affairs of these countries, but it does mean that the United States cannot remain indifferent to the existence of conditions which menace the fundamentals of civilization.

The positive principles of foreign policy which this exceptional situation demands, rest in part on the fact that the sections of the American continent above referred to have become important sources of the food supply of the American people, and that the possibility of reducing the cost of living of the American workingman depends in large measure on the uninterrupted use of these sources of supply.

This does not mean that the United States should pursue a selfish or ruthless policy in dealing with these countries. On the contrary, the permanent interests of the United States are best subserved by prosperous, independent, self-respecting and progressive neighbors. Our policy toward them should be conceived in the most elevated spirit of helpful coöperation, but the basis of this coöperation should be and must be the maintenance of the fundamental requisites of civilization.

The Monroe Doctrine was formulated to accomplish two specific purposes:

1st. To prevent further European colonization on the American continent, and

2d. To prevent the extension of the European political system to the United States, the overthrow of the domestic institutions of an American state by European influence, or the control of the political destinies of an American state by any European power.

These two leading principles, which were of an essentially negative character are still vital principles of the foreign policy of the United States, in the maintenance of which every state of the American continent is deeply interested. The cordiality of our relations with the countries of South America demands that the Monroe Doctrine be limited to its original content. If this is done, there need be no fear of wounding the sensibilities or arousing the opposition of the countries of South America.

When, therefore, in our relations with the islands of the West Indies, with Central America or with Mexico, it becomes necessary to go beyond the negative principles of the Monroe Doctrine, and enforce positive principles of foreign policy, let us take such a step fully cognizant of the fact that we are not acting under any supposed principles of the Monroe Doctrine, but on the basis of a policy dictated by the requirements of the special conditions in the Mediterannean section of the American continent. Special agreements looking toward coöperation for the maintenance of stability, such as the reorganization of the San Domingan finances, do not rest on any principle of the Monroe Doctrine, but are dictated by the exceptional relationship above referred to.

Our Mexican policy is another of the influences that has reacted unfavorably upon the international position of the United States. No one will doubt for a moment the lofty ideals which have actuated the President in the formulation of his policy, but it is also clear that in spite of all protestations to the contrary our Mexican policy has aroused a marked feeling of opposition amongst the peoples of Central and South America, and has served to foster secret understandings between European governments for the purpose of protecting what they regard as their national rights and the rights of their citizens. We must always bear in mind that whatever may be our personal views with reference to the Monroe Doctrine it has always been regarded by the European countries as an expression

of the intention of the United States to reserve the countries of the American continent as a special field for its commercial and industrial influence.

The unwillingness of the United States to allow European governments to intervene in Mexico for the protection of the interests of their citizens and subjects, combined with the reluctance of the United States to accept the full responsibilities which this position involves, has served to accentuate the feeling of opposition to the United States which has been growing so rapidly within recent years.

Furthermore, the attempt on the part of the President to deal with the Mexican situation as if it were part of a general Latin-American problem instead of facing it squarely as a problem *sui generis*, involving an exceptional relationship between neighboring countries, has aroused the bitter opposition of the countries of Central and South America. The insistence of the United States on the retirement of a provisional President is looked upon as a form of unwarranted dictation, and as an indication of a settled purpose on the part of the United States to assert a kind of political supervision over the republics of the American continent.

In conclusion, I desire to refer to a recent occurrence which has given rise to serious misgivings both in Europe and in the countries of Central and South America. In an address delivered before the Southern Commercial Congress, the President of the United States announced a new principle of American foreign policy, the purpose of which seems to be the gradual financial emancipation of the countries of Central and South America from their present dependence on European capital. In the course of this address, the President attacked

"the material interests that had influenced the foreign policy of certain Governments in their relations with the nations of Latin-America."

He declared it to be the duty of the United States,

"to assist the nations of this hemisphere in their emancipation from the material interests of other nations, so that they might enjoy constitutional liberty unrestrained." "You hear," he said, "of concessions to foreign capital in Latin-America . . . States that are obliged to grant concessions are in the position that foreign interests are apt to dominate their affairs. Such a state of things is apt to become intolerable. It is emancipation from this inevitable subordination that we deem it our duty to assist."

It is true that the President restricted himself to a declaration against "concessions," and it would seem that to his mind this term involves the idea of special privilege or monopoly. The nearest English equivalent of the Spanish word "*concesión*" is our own legal term "franchise." It is true that in many of the countries of Central and South America such franchises include the grant of monopolistic privileges. It is also true that under the cloak of such franchises many abuses have been committed, but we must bear in mind that the unsettled political conditions prevailing in many of these countries and the exceptional risks to which foreign capital is subjected, have made it necessary to offer exceptional inducements in order to attract foreign investors. If we stop to reflect on the extraordinary inducements which were offered to foreign capital during the early history of the United States, and on the great service which such capital rendered to our national development, we can readily see that any policy, the effect of which is to discourage foreign investments in Central and South America, cannot help but retard the development of those sections of the continent. We may deplore the fact that in many of the republics of the American continent there has been a wasteful and at times a corrupt distribution of franchises and special privileges, but it is a serious question whether it is either our duty or our right to undertake to determine or even to suggest the standards or conditions to which the investment of foreign capital should conform.

At all events, let us not close our eyes to the fact that the formulation of this policy has aroused serious misgivings throughout the countries of the American continent, as it is looked upon as an unwarranted assumption of control over their liberty of action. In Europe the President's pronouncement is regarded as confirmatory of a suspicion, which has been growing within recent years, namely that the United States has embarked upon a national policy, the purpose of which is to reserve the less advanced countries of the American continent for the economic exploitation of American capital.

Whatever the ultimate judgment on the appropriateness of the principles or the wisdom of the policy formulated in the President's Mobile speech, it should be made clear that this new orientation of

our foreign policy is not a part of the Monroe Doctrine, and has no organic relation to the fundamental principle upon which the Monroe Doctrine rests, namely, national safety and self-protection. It is a new and strange principle which has aroused the opposition of the countries for whose benefit it is intended, and has engendered bitterness of feeling amongst European peoples. If it is to be maintained it must justify itself by basic reasons of national interests and international obligation entirely independent of the Monroe Doctrine.

These, in brief, are the more important influences that have aroused the opposition of many sections of the American continent and the animosity of Europe, and have placed the United States in a position of international isolation. It would be idle to argue that we have been the victim of circumstances because, as we have seen, the position in which the United States finds herself at the present time is traceable to the fact that our national thought and national consciousness have not kept pace with our international responsibilities. The most serious aspect of this condition of isolation is that it prevents us from fulfilling the high mission in international affairs which, by reason of our exceptional geographical position, by reason of our exceptional relationship to European as well as to American affairs, we are manifestly called upon to perform. The words spoken by Mr. Root at the Fourth Pan-American Conference at Rio Janeiro set the standards which should ever remain before the American people:

> "We wish for no victories but those of peace; for no territory except our own; for no sovereignty except the sovereignty over ourselves. We deem the independence and equal rights of the smallest and weakest member of the family of nations entitled to as much respect as those of the greatest empire, and we deem the observance of that respect the chief guaranty of the weak against the oppression of the strong. We neither claim nor desire any rights, or privileges, or powers that we do not freely concede to every American Republic. We wish to increase our prosperity, to expand our trade, to grow in wealth, in wisdom and in spirit, but our conception of the true way to accomplish this is not to pull down others and profit by their ruin, but to help all friends to a common prosperity and a common growth, that we may all become greater and stronger together."

THE MORPHOLOGY OF THE PASSAMAQUODDY LANGUAGE OF MAINE.

BY J. DYNELEY PRINCE.

(Read April 25, 1914.)

The Passamaquoddy Indians of Maine, together with the Maliseets (Milicetes) or St. John's River Indians of New Brunswick form a single linguistic group of the eastern Algonquin family known as *Wabanaki*,' people of the dawnland,' or 'East.' It is estimated that there are about three hundred and fifty people in each clan. The other members of the group are the Micmacs of Nova Scotia, the Abenakis (a corruption of Wabanaki) or St. Francis Indians of Quebec, and the Penobscots of Oldtown, Maine, the two latter clans also forming a linguistic group similar to that of the Passamaquoddies and Maliseets.[1] The name "Passamaquoddy" is a corruption of *pestumo'kat*, 'one who catches pollack fish' (*Gadus Pollachius*) = *peska'tum*. This term has been applied to the tribe only in comparatively recent times. The headquarters of the Passamaquoddies are at Pleasant Point, Maine (*Sipáyik*), where the remnants of the tribal organization still exist. Here, for example, dwelt Sopiel Selmo, the keeper of the Wampum Record, a mnemonic system of wam-

[1] For the Wabanaki group, cf. my articles: "Notes on the Language of the Eastern Algonquin Tribes," *Amer. Jour. Philol.*, IX., pp. 310–316; "The Wampum Record," *Proc. Amer. Philos. Soc.*, 1897, pp. 479–495; "Forgotten Indian Place-names in the Adirondacks," *Jour. Amer. Folk-Lore*, 1900, pp. 123–128; "Some Passamaquoddy Witchcraft Tales," *Proc. Amer. Philos. Soc.*, XXXVIII., pp. 181–189; "Notes on Passamaquoddy Literature," *Annals N. Y. Academy of Sciences*, XIII., pp. 381–386; "The Modern Dialect of the Canadian Abenakis," *Miscellanea Linguistica in Onore di Graziodio Ascoli*, 1901, pp. 343–362; Leland and Prince, "Kulóskap the Master," Funk and Wagnalls, New York, 1902; "The Algonquin Noun," Proceedings of the Congress of Orientalists, Rome, 1904; "Algonquin Religion," Hastings, Dictionary of Religions, s. v. "God"; "A Micmac Manuscript," Proceedings of the Congress of Americanists, Quebec, 1908; "A Passamaquoddy Aviator," *Amer. Anthropologist*, XI.

pum shells arranged on strings in such a manner, that certain combinations suggested certain sentences or ideas to the narrator, who, of course, knew his record by heart and was merely aided by the association of the shell combinations in his mind with incidents of the tale, song or ceremony which he was rendering (Prince, *Proc. Amer. Philos. Society,* December 3, 1897, pp. 479–495). With Selmo, however, died the secret of this curious system, but the laws and customs thereby recorded have been preserved and published in the *Proceedings of the American Philosophical Society* (*loc. cit.*). There is also a large amount of oral literature handed down by these Indians, a quantity of which exists in the manuscripts of the Hon. Lewis Mitchell, Indian member of the Maine Legislature. These documents are now in my possession and I expect to publish their material in an exhaustive work on the Passamaquoddy tribe and language. Some matter of this character has already appeared, both in the *Proceedings* of this Society (XXXVIII., pp. 181–189), and also in Leland and Prince, "Kulóskap the Master," New York, 1902, a popular exposition of the eastern Algonquin folk-lore.

The object of the present paper is to discuss briefly the chief peculiarities of the Passamaquoddy idiom, as it is now in use. No detailed presentation of the morphology of this dialect has been made as yet, although some of its features have been noticed. Nearly all the materials for the present article have been gathered orally from the Passamaquoddies and tested by means of the Mitchell manuscripts.

PHONETICS.

The phonetics of the dialect are comparatively simple. The system followed herein gives to the vowels the Italian pronunciation, except *â* = English *aw* in 'awful' and the indeterminate vowel (*Schwund*) which is indicated by the apostrophe '. There are no nasal vowels in Passamaquoddy, as in Abenaki. *H* has the value of the simple breathing, but the inverted comma ' is the well known Algonquin glottal catch, pronounced like a very soft Arabic medial *Ḥe*. *Ch* often represents a palatal *tsʸ* and between vowels has a tendency to approach *j* = *dsʸ*. The constants *p, t,* k are voiceless surds often approaching *b, d* and hard *g* between vowels, but never

uttered like the English *p*(*h*), *t*(*h*), *k*(*h*). *S* between vowels is sometimes occasionally pronounced almost *z*. The combination *w'* is the whistle peculiar to the Algonquin languages occurring at the end of syllables: *ke'kw;* pronounced *keḥkwu*. *W* in general is a weak consonant; it is almost equivalent to the *u*-vowel. It generally disappears after any prefix, as seen in the paradigm of *wikwus: nikwus; kikwus*, etc. It should be noted that the *l* carries an inherent vowel and is consequently pronounced very like the Polish barred *l*. *N* before consonants, as in the syllables *nta-; nki-* is pronounced with its own inherent vowel *'n*. The spelling of the Mitchell manuscripts is a mixture of English and French influences, frequently using *b, d, g* for *p, t, k; j* for *ch* and an arbitrarily varying system of vocalization. No attempt has been made to follow it in this paper.

The Passamaquoddy is not especially rich in consonantal clusters, although more so than some of the other Algonquin idioms, as for instance the Fox. The following table covers nearly all the consonantal groupings which appear, and even some of these are not true clusters, as they occur in many cases with vocalic *w* and *y*. The Indian manuscripts show many apparent clusters, but they are often really separated by the *Schwund* which no Indian ever writes. Thus clusters with *l, m, n* are suspicious, owing to the probability of inherent vowels. The *Schwund* and inherent vowels may be represented by *e*.

Clusters.

chw: echwéchi, 'must.'
chy: apachyáie, 'when I come.'
k'm: w'-mikmaupaul'tínia, 'they feast together.'
ks: ēyiks, 'when they are' ('were').
kskw: chwopnokskwâk'n, 'anchor.'
kt: w'máche-m'siktihîk'n, 'he begins to punish him,' but here the *k* probably represents *k'*.
kw: akwét'n, 'canoe.'
kw'p: nisukmékw'p'n, 'as we (paddled) together.'
lk: túlkiu, 'thus' (real).
lh: amalhi'takwuk, 'they make music'; *hel'* 'fawn.'
lkw': alkw'minaútikuk, 'in their midst' (suspicious).

lp: hólpin, 'he sits.'
lt: -toltîtit = participial ending 3 p. pl. (real).
mk: el-ámkikap, 'when they came ashore.'
mkw': kikúmkwuk, 'suckers' (fish).
ms: n-olámsittam'n, 'I pretend to': *lams-,* 'blow.'
msk: ámskowás, 'first.'
nk: (nasal): *k'tunkian,* 'when you have hunted' (real).
nk: ankwoch, 'sometimes' (real).
ns: nsámakwán, 'water' (*n* with inherent vowel: *'n*).
pk: apkulámsek, 'they are overwhelmed by the wind.'
pkw': achápkwalusk, 'perch' (fish).
pn: chwopnokswâk'n, 'anchor' (not *p'n*).
ps: ásups, 'grebe' (sort of crane).
psk: ápskeduk, 'than.'
pt: appatáptow'k, 'they come back'; *náchipt,* 'fetch' (imper.).
pw: apwitowatíchil, 'they stand.'
sh: apakweshes, '*red-headed* wood-pecker' (= *s-h;* not the English *sh*).
sk: mosk, 'find.'
skw': peskw, 'one.'
sm: iklísm'n, 'white man' = 'Englishman'; *ismékwes,* 'fish-hawk.'
sn: p'snut, 'basket.'
sp: kúspem, 'lake'; *spāswēu,* 'morning.'
st: chestésit, 'he being angry'; *stáknut,* 'green.'
sw: k'loswâk'n, 'word.'
th: petholatíchihi, 'when they arrive.'
tk: atkéyi, 'string, cord'; *uskitkamikw,* 'world.'
tm: chepakatm'n, 'that you shall marry.'
ts: mits, 'eat' (imper.).
tsk: mitskun, 'animal dung.'
tw: lakutwâk'n, 'treaty.'

The intonation of the Passamaquoddy is highly tonic. Almost every accented syllable indicates a voice-lift. The voice is dropped on the syllable following the tone; half raised again on the third syllable and dropped again on the fourth: *lakutwâk'n;* pronounced $^{la}kut^{wâ}k'n$. This peculiarity appears to be distinctively Passama-

quoddy, as the kindred Maliseets speak very monotonously and with no especially noticeable voice-lift on the accented syllable. The Abenakis also have a monotonous tone, amounting practically to a drawl.

MORPHOLOGY.

In Passamaquoddy, as in all the other Algonquin idioms, the words are really only indifferent themes, which may be used either in a nominal or a verbal sense. This phenomenon is too well known to require elaboration, but it may be illustrated by the appearance of such indeterminate roots in all the parts of speech; thus, *sak,* 'be strong, rule'; as seen in *w't-ach'wi-saki'tón'l,* 'he must rule'; *saklēyo,* 'it is hard, difficult'; *saklikwáso,* 'it is served up strong'; *sákem,* 'chief'; *sak'mawámat,* 'he who is chief'; *k'ti-sak'mawé'lul,* 'I wish to make you chief'; *sák'ma-wíkwām,* 'chief's house'; *sak'mawel-mékw'tech,* 'may it be hallowed'='made like a chief,' etc. Similarly, the root *os,* 'shine,' appears in *kís-os,* 'luminary' (probably= 'what can [*kis*-] shine'); hence='moon, month'; *el-āse,* 'what shines'; *nip-aúsit,* 'what shines at night'; specifically 'the moon' (*nip*='night'), etc. (see just below on *w'li*).

The Substantive.

All substantives, including adjectival formations, are divided into two classes, animate and inanimate, no attention being paid to sex-gender, which is expressed either by prefixing or suffixing some determining word, or else by the use of a distinct expression; *kínche-més,* 'king' (literally: 'King James,' the name of the first king whose name the Indians heard); but *kínchemes-iskwé,* 'queen,' with the feminine suffix *-iskwé* (='squaw'); *mûin,* 'bear,' but *nápeskw,* 'she-bear'; *pût'p,* 'whale,' but *skwemé'kw,* 'she-whale,' etc. It should be noted that many substantives which we should regard as inanimates are treated as animates in Passamaquoddy and conversely; as *akim,* 'snow-shoe' (an.); but *sat-y-il,* 'blue-berries' (inan. pl.). Genuine inanimates are, *e. g., t'm'hîk'n,* 'axe'; *wik-wam,* 'house,' and words of a similar character.

The plural ending for animate nouns is invariably *-k* and for inanimate *-l,* preceded as a rule by indeterminate connecting vowels;

mûs, 'moose'; pl. *mûs'k; ěs*, 'clam'; pl. *ěs'k*. Nouns ending in *-p* and dentals like *skí'tap*, 'man,' insert *-y-* and use the distinct ending *-ik;* pl. *skitápyik;* cf. also *pílchisáp-yil*, 'trouser-braces' (inan.); *piljis* = English 'breeches' + *ap*, 'hang'; lit. = 'hang-breeches.' Participial forms in *-t*, like *épīt*, 'woman,' palatalize the *ty* into *ch;* pl. *épichik* for *èpityik*. The same phenomenon of *y* after labials and dentals appears in *wikhîk'nepyéi*, 'inkstand' (*wikhîk'n-nep*, 'book-water' + *-ei*, 'thing'), and in *met-y-ēwéstakw*, 'he is saying' (*met-* = prolonged action + *y* + *ēwest*, 'speak' + participial ending *-akw*). Note also *sat-y-il* (inan.), 'blue-berries.' I can find no trace of the connecting vowels *a*, *o* and *e* (*i*) used after specific consonants, as in Abenaki (cf. Prince, "Ascoli Memorial," p. 349). Sometimes, however, after *-s* a plural in *-w'k* occurs, as *kísos*, 'month'; pl. *kis'w'k*, but, on the other hand, *kakakûs*, 'crow'; pl. *kakakûs'k*. There seems to be a natural affinity in the labial and dental for the connecting *-y-*.

THE ADJECTIVE.

Adjectives may be used as separate indeclinable particles preceding the noun; as *k'chî skí'tap*, 'great man'; *sigi m'tápekwin*, 'fierce warrior.' They may also appear in this indeclinable form adverbially, as *kátamayíwi-k'túnkiyik*, 'while absent they hunt' (lit. 'not' = *katama* + *y*, connecter, + 'being' = *i-wi*). Very common is the use of adjectives ending in *-ko* for animates and *-k'n* for inanimates: *w'lîko skí'tap*, 'good man'; pl. *w'lîkow'k skitápyik; w'lîk'n wíkwām*, 'good house'; pl. *w'lîkn'l wíkwām'l*. The participial *-it* (an.) and *ek* (*ik*) (inan.) is a common adjectival ending as *w'lîkit*, 'handsome' (an.); *w'lîkek* (inan.). When the adjective is inflected, it must agree with its nouns, which it may follow or precede: *sắks'l picheyíkil*, 'long stockings' (= *sāks'l*). Some adjectives end in *-l*, as *nék'm'kil skí'tap*, 'big man,' which is not an obviative *l* (see below, Substantival Modifications, No. 1). Adjectives may be formed from nouns by the endings *-wi* as *skitáp-wi*, 'human,' and *-(k)ewi: wíkwamkéwi*, 'homelike.'

The element *w'lî-*(*oli-*) may also be used adjectivally without inflection, as *w'lî haás*, 'good horse'; *w'lî wíkwām*, 'good house,' and in innumerable combinations both nominal and verbal. Per-

haps no better example of Passamaquoddy polysynthetic formation can be had than the following partial list of the combinations possible with *w'lî: w'lithátm'n,* 'he is glad of it'; *k-elwut,* 'good'; *w'lămto,* 'he is good natured'; *w'lásewanwechiyánia,* 'they are pleased with him'; *w'laswĕlt'm'n,* 'he thanks for it'; *olilĕlm'len,* 'as I wish you well'; *olínm'n'l,* 'he rejoices at it'; *w'lápémkuk,* 'it benefits hims'; *uliotwâk'n,* 'benefit' (n.); *w'l-wíku,* 'he lives well'='is rich'; *w'tách'wi-w'l-ánkeyowáw'l,* 'they must take good care of him'; *w'lapĕwit,* 'beautiful'; *w'lapĕwiŭ,* 'handsome man'; *w'leyów'l,* 'he treats her well'; *w'litham'l,* 'he consents'; *w'l-okhedím'k,* 'sport, game,' etc.

THE PRONOUN.

The demonstrative pronouns are *yut,* 'this' (nearer); *wut,* 'this'; *na,* 'that,' indeclinable; and *nit, nit,* 'that.' See below for the obviative inflection. The relative for both classes and numbers is *eli-,* followed by the participle: *eli-uskichínwit,* 'he who is an Indian'; *eli-meksit,* 'who finds.' Sometimes the relative is expressed by the participle alone: *askowaltíchik,* 'those who wait.' The interrogative pronoun is as follows: animate *wen,* 'who'; obv. *wen'l;* also='someone'; obviative pl.=*wenihi;* inanimate: *ke'kw,* 'what'; also='something'; pl. *ke'kw's'l,* 'some things, things.'

A highly important feature of the language is the combination of both nouns and verbs with personal pronouns, by which means most of the inflection is carried on. In the following table of personal pronouns, it will be observed that the Passamaquoddy, like its Algonquin congeners, has two first persons plural; an inclusive and an exclusive, the first of which implies that the person and persons addressed are included with the speaker, while the second form excludes the person or persons addressed; *i. e.,* the first='I, you' and 'they,' and the second='I' and 'they.'

Separable Personal Pronouns.

I, *nĭl.*	We (incl.), *kîl'n.*
Thou, *kĭl.*	We (excl.), *nîl'n.*
He, she, it, *nĕg'm.*	You, *kîl'wau.*
	They, *nĕg'mau.*

The primitive elements of the first, second and third persons are *n, k* and *w(o)*, prefixed in the separable pronouns above to certain demonstrative elements which are practically identical in all the dialects. These elements *n, k, w(o)* may also be prefixed to nouns, to indicate possession, and to verbs, to denote conjugational inflection. It will be noticed, however, that the separable pronoun of the third person is represented by a demonstrative particle *neg'm* (Abenaki *ag'ma;* Delaware *nekama*). This has no connection with the *w(o)*-prefix, but is a combination of the ordinary demonstrative *n(a; ni)*, 'that one' + the asseverative *ga,* seen in *gak* (*passim*), and the possessive *-m* (see below).

The following diagram will illustrate the Passamaquoddy method of combining the pronominal *n, k, w(o)* with the animate and inanimate forms of nouns in order to denote the possessive relation.

DEF. AN.

nimía níkwus, 'I see my mother.'
k'nimía kíkwus, 'Thou seest thy mother.'
w'nimíal wikwús'l, 'He sees his mother.'
k'nimiánna kikwús'n, 'We (incl.) see our mother.'
nimianna nikwús'n, 'We (incl.) see our mother.'
k'nimiáwu kikwús'wu, 'You see your mother.'
w'nimiáw'l wikwús'w'l, 'They see their mother.'

DEF. INAN.

nimí'ton nt'm'hîk'n, 'I see my axe.'
k'nimí'ton k't'm'hîk'n, 'Thou seest thy axe.'
w'nimí'ton w't'm'hîk'n, 'He sees his axe.'
k'nimí'tonen k't'm'hîk'nen, 'We (incl.) see our axe.'
nimí'tonen n't'm'hík'nen, 'We (excl.) see our axe.'
k'nimi'tónia k't'm'hík'n'wu, 'You see your axe.'
w'nimi'tónia w't'm'hîk'n'wu, 'They see their axe.'

DEF. AN. PLURAL.

nimíuk nikwús'k, 'I see my mothers.'
k'nimîuk kikwús'k, 'Thou seest thy mothers.'

w'nimia wikwus, 'He sees his mothers.'
k'nimiánnawa kikwúsn'w'k, 'We (incl.) see our mothers.'
nimiánnawa nikwúsn'w'k, 'We (excl.) see our mothers.'
k'nimiáwu kikwús'w'k, 'You see your mothers.'
w'nimiáwu wikwusw'l, 'They see their mothers.'

Def. Inan. Plural.

n'mi'ton'l nt'm'hîk'n'l, 'I see my axes.'
k'nimi'ton'l k't'm'hîk'n'l, 'Thou seest thy axes.'
w'nimi'ton w't'm'hîk'n'l, 'He sees his axes.'
k'nimi'tonén'w'l k't'm'hîk'nen'l, 'We (incl.) see our axes.'
nimi'tonén'w'l n't'm'hîk'nen'l, 'We (excl.) see our axes.'
k'nimi'ton'w'l k't'm'hîk'n'w'l, 'You see your axes.'
w'nimi'ton'w'l w't'm'hîk'n'w'l, 'They see their axes.'

Indef. Animate.

nimia wikwus, 'I see a mother'; *wikwus'k,* 'mothers.'
k'nimia wikwus, 'Thou seest a mother'; *wikwus'k,* 'mothers.'
w'nimia wikwús'l, 'He sees another'; *wikwus.*
k'nimiáp'n wikwus, 'We (incl.) see a mother; *wikwus'k,* 'mothers.'
nimiáp'n wikwus, 'We (excl.) see a mother'; *wikwus'k,* 'mothers.'
k'nimiá'pa wikwus, 'You see a mother'; *wikwus'k* 'mothers.'
w'nimiánia wikwus'l, 'They see a mother'; *wikwus,* 'mothers.'

Indef. Inanimate.

nimi'to t'm'hîk'n, 'I see an axe'; *t'm'hîk'n'l,* 'axes.'
k'nimi'to t'm'hîk'n, 'Thou seest an axe'; *t'm'hîk'n'l,* 'axes.'
w'nimi'to t'm'hîk'n, 'He sees an axe'; *t'm'hîk'n'l,* 'axes.'
k'nimi'tonēp'n t'm'hîk'n, 'We (incl.) see an axe'; *t'm'hîk'n'l,* 'axes.'
nimi'tonēp'n t'm'hîk'n, 'We (excl.) see an axe'; *t'm'hîk'n'l,* 'axes.'
k'nimi'tó'pa t'm'hîk'n, 'You see an axe'; *t'm'hîk'n'l,* 'axes.'
w'nimi'tow'k t'm'hîk'n'l, 'They see an axe'; *t'm'hîk'n'l,* 'axes.'

The scheme of the possessive prefixes and suffixes for nouns is then as follows:

Animates.		Inanimates.	
Singular.		Singular.	
n——	*k——'n*		*k——en*
k——	*n——'n*	*n——'l*	*n——en*
w——l	*w——w'l*	*k——*	*k——'wu*
	w——w'l	*w——*	*w——'wu*
Plural.		Plural.	
n——k	*k——n'w'k*	*n——*	*k——-en'l*
	n——n'w'k		*n——-en'l*
k——k	*k——w'k*	*k——'l*	*w——w'l*
w——(i, o)	*w——w'l*	*w——'l*	*k——w'l*

When a noun begins with a vowel or with an *l* (really *'l* with inherent vowel), a dental is inserted after the pronominal prefix: ***nt-akim,*** 'my snow-shoe'; ***nt-latwewâk'n,*** 'my language.' When a noun begins with *w,* as *wíkwus,* the *w*-prefix coalesces with the initial, as shown above. Many substantives beginning with ***m,*** especially those denoting a part of the body, lose their ***m*** when inflected possessively: ***m'huk,*** 'body'; ***n'huk,*** 'my body,' etc.

Substantival Modifications.

The following seven noteworthy modifications of the substantive appear in Passamaquoddy:

1. The so-called obviative or accusative-ending of the third person occurs only when the animate noun stands in connection with a verb or possessive pronoun in the third person. There is no inanimate obviative. This accusative, which is peculiar to all the Algonquin dialects, is denoted in Passamaquoddy by *-l* in the singular, and in the plural often by the absence of any ending, or by *-i, -o.* The following instances will suffice to illustrate the application of this form: (*a*) ***w'nimíal haásw'l,*** 'he sees the horse,' but ***k'nimía haás,*** 'thou seest the horse'; (*b*) ***w't-aásw'l,*** 'his horse'; pl. ***w't-aás,*** 'his horses'; ***wikwús'l,*** 'his mother'; pl. ***wikwus,*** 'his mothers'; (*c*) to express a dative relation: ***w'mílan haásw'l skitápyil,*** 'he gives (him) the horse to the man,' but ***k'mílen haás,*** 'I give thee a horse'; cf. also in the participle: ***nōtáchil,*** 'those who hear him.' As to form, note the sing. obv. ***skitápyil,*** 'man'; ***mûinyil,*** 'bear,' but pl. ***skitá'pihi; mûini; haáso; mûso,*** 'moose'; ***ma'tekwéss-o,*** 'rabbits';

wá'sis, 'children'; *hamwes,* 'bees.' Note the double obv. ending in *ép'sîyil,* and also regularly *ép'sî,* 'trees,' from *ep's.* The obv. pl. is irregular in the demonstrative pronouns, which are inflected as follows: *wut,* 'this'; obv. sing. *wut'l,* and *wahat;* pl. an. *wut'k;* obv. *wutihi* (often *wahat*); pl. inan. *wut'l; yut,* 'this' (nearer); obv. sing. *yut'l,* and *yahat;* pl. an. *yukt,* obv. *yu'tihi* (often *yahat*); inan. pl. *yu't'l; na,* 'that' (indeclinable); *ni, nit,* 'that' (nearer); obv. sing. *ni't'l,* and *nihit;* pl. an. *nikt;* obv. *nihit* (rarely *ni'tihi*); pl. inan. *nilt'l.* The distinction between the singular and plural obviative is often not observed, even in nouns and verbs.

This case frequently appears as the subject of a sentence. *pechihalina w'skinosís'k w'nichálkw'l,* 'then comes the lads' uncle'; *mach'kowdîtit pesēsmowi nisumatíchihi,* 'as soon as their star-husbands have gone away.' Sometimes the obviative is omitted entirely: *w'néklan lámp'kwinóskwesís'k,* 'he leaves the water-sprites'; a fairly common phenomenon. The obviative frequently appears in verbs: *wítāpekamáspenihi,* 'he was a friend to them.'

There is no trace in Eastern Algonquin of the so-called surobviative or third personal accusative of the Cree and Ojibwe.

2. The locative-instrumental is expressed by *-k;* pl. *-ikúk,* which has the force of a number of English prepositions; viz., 'at, by, from, in, into, on, to,' according to the directive force of the verb with which it stands in construction: *Péssank,* 'at Bar Harbor'; *kowás'k,* 'by means of a log,' a common locution; *wéchi-notgát'wul-to w'tûn'k,* 'they crawl out of his mouth'; *móskesí'to paskán'wikúk,* 'he crawls out of the pits'; *wíkwām'k,* 'in' or 'into the house,' according to the sense of the verb; *kowásnok,* 'on a log'; *k'm'tkinans'n'k,* 'to our land,' etc. The locative *-k* is regularly inflected with the possessive suffixes as follows: *nt'm'hîk'nk,* 'on my axe'; *k't'm'hîk'n'k,* 'on thy axe'; *w't'm'hîk'nk,* 'on his axe'; *k't'm'hîk'n'n'k,* 'on our axe' (incl.); *nt'm'hîk'n'n'k,* 'on our axe' (excl.); *k't'm'hîk'n'w'k,* 'on your axe'; *w't'm'hîk'n'w'k,* 'on their axe.'

3. The vocative element *-tuk* as in *nitapé'tuk,* 'O my friends'; *wásistuk,* 'O my children,' used only with the plural, had originally a dubitative meaning = 'as many as there are.' This force is still existent in Cree and Ojibwe.

4. The possessive suffix *-m* contains the same demonstrative element as the *-m* of *neg'm,* 'he, she, it': *nt-aás'm, k't-aás'm,* 'my, thy horse,' etc.

5. The diminutive *-sis* is very common: *t'm'hîk'nsís,* 'little axe'; *pílskwesís,* 'girl' (*pil,* 'young' + *skwe,* 'woman' + *sis*), etc.

6. Here must be noted also the movable future *-ch,* which may be affixed indifferently to nouns or to verbs: *k'nimíol-ch,* 'I shall see you,' but *wikwām-ch nimí'ton,* 'I shall see the house.' There is another more vivid future expressed by *lî,* 'go,' preceding the verb: *k't'lî-nimíol,* 'I shall (am going to) see thee.'

7. Finally in this connection, similar to the *-ch* is the movable conditional particle *-p,* as *nt'liáp'n'p sámakwān'k skatúchi pískononōk,* 'we (excl.) should go upon the water, if there were no fog'; here with the verb, but *tahalo-p ke'kw-yali kwilwatakw,* 'as if they were seeking something' (*ke'kw*). Sometimes this appears doubled: *nil'p-lo nt-étum-níswinén'p,* 'I should take it along.'

So far as I am aware there is no interrogative state such as occurs in Ojibwe. As in all Algonquin dialects, the genitive relation is expressed often by means of simple apposition: *aut niméskw'k,* 'road (*aut*) of the spirits'; *ótenesís w'lî-p'maus'wín'w'k,* 'a village (*otenesis*) of good people'; often, however, by the locative *-k; sipsís'k skwú't'k,* 'birds of (in) fire' (*skwu't'k*). Sometimes the genitive is indicated by the possessive relation: *w'skínōsís w'nichálkw'l,* 'the lad his uncle'.

As shown above, the dative is expressed by means of the verb and obviative substantive, if the verb is in the third person.

THE VERB.

The imperative is the simplest form of the verbal root, as is the case in most languages; thus: *kwaskw,* 'run thou'; *kwaskw'híkw,* 'run ye'; *kwaskwech,* 'let him run.'

The present tense is the main tense of the Passamaquoddy verb, as from it the future, conditional and past are formed by means of suffixes. In fact, it may be truly said that the present is the only real tense of the language. The present is often used for the past in vivid narrative. The following example of the present of the

intransitive stem *p'mauso-*, 'walk, live' (=*p'mî*=prolongation + *aus*, 'live'), will suffice to show the combination of this intransitive form with the pronominal elements: ***np'maus***, 'I walk'; ***k'p'maus***, 'thou walkest'; ***w'p'maúso***, 'he walks'; 'is walking'; ***k'p'maús-îp'n***, 'we (incl.) walk'; ***np'maús-îp'n***, 'we (excl.) walk'; ***k'p'maús-í'pa***, 'you walk'; ***w'p'maús'w'k***, 'they walk.' Note also the participle ***p'múiso***, 'he is in the act of walking'; ***kwen-aúsit***, 'as long (***kwen***) as he lives,' or ***m'sî-eli-p'maúsit***, 'all the time (***m'sî***) while (***eli-***) he lives.' Sometimes the singular of the intransitive verb ends in ***-in***: ***n'kwáskwin***, 'I run'; (***k'***)***kwáskwin***, 'thou runnest'; ***w'kwásk-win***, 'he runs.'

The combination of the pronominal elements with the transitive verb is the most difficult feature of the language and is sufficiently illustrated by the following paradigms and scheme of prefixes and suffixes. Note that all forms marked in the following schedules with a single asterisk are indefinite; those with two asterisks show a dative force (cf. **We—Thee,** Incl. in the Paradigm); forms with three asterisks have both indefinite and definite force, while all forms not designated are definite. All forms in Italics are negative and must be preceded by the negative particles ***kat, katama, skat***, 'not.' All forms in Roman are positive. The ***-ep, -p, -s, -epus*** forms in parentheses indicate the imperfect or conditional-subjunctive. **Ind.** = Indefinite; **Def.** = Definite; **P:** = the Imperfect (Past); **An.** = Animate; **Inan.** = Inanimate. All forms in Roman are positive.

PARADIGM OF NIM—"TO SEE."

I—Thee: k'nimíol(-ep); ***k'nimiólo(-p; -pus)***. When the verb-stem ends in -l, as mil, 'give,' this form becomes k'milen.

I—Him-Her:[3] nimía (-p); ***nimiáwi (-p; -s)***.

I—It: Ind. nimi'to (-p'n); ***nimi'towi (-p; s)***. **Def.** nimi'ton(-ep); ***nimi'towun (-ep)***.

I—You: k'nimiólpa (-p); ***k'nimioló'pa(-pus)***.

I—Them (An.): Ind. nimía; ***nimiawíwu (-p)***. **Def.** nimíuk; **P.** nimiápenik; ***nimiawíwuk;*** **P:** ***nimiawiwápenik***.

[3] In this verb, the forms: ***nimía, nimi'to, nimi'ton'l*** stand for ***n'nimía, n'nimi'to***, etc., with the prefix ***n'*** of the first person, assimilated to the ***n*** of the verbal root. The second personal ***k'*** also assimilates to a ***k***-stem: ***kwás-kwin***, 'thou runnest.'

I—Them (Inan.): nimí'ton'l; **P:** nimi'tonépenil; *nimí'towunul;* **P:** *nimi'towunépenil.*

Thou—Me:[4] k'nimí-h-i (-p; -pus); *k'nimihíwi(-p).*
Thou—Him-Her: k'nimía(-p); *k'nimiáwi(-p).*
Thou—It: **Ind.** k'nimíto(-p); *k'nimi'towi(-p).* **Def.** k'nimíton(-ep); *k'nimí'towun(-ep).*
Thou—Us: k'nimiáp'n(-ep; -es); *k'nimiawíp'n (-ep).*
Thou—Them (An.): **Ind.** k'nimía; *k'nimiawíwu.* **Def.** k'nimíuk; *k'nimiawíwuk;* **P:** k'nimiápenik; *k'nimiawiwápenik.*
Thou—Them (Inan.): **Ind.** k'nimi'tónia; *k'nimi'towuno.* **Def.** k'nimi'ton'l; *k'nimí'towun'l.*

He-She—Me: nimióg'n(-ep); *nimióg'wi(-p).*
He-She—Thee: k'nimióg'n(-ep); *knimióg'wi(-p).*
He-She—Him-Her: **Ind.** w'nimía(n);[5] *w'nimiáwi (-p'n).* **Def.** w'nimíal; **P:** w'nimiáp'n; *w'nimiawíwul;* **P:** *w'nimiawíp'n.*
He-She—It: **Ind** w'nimi'to (-p) *w'nimi'towi(-p).* **Def.** w'nimi'ton(-ep); *w'nimi'towun(-ep).*
He-She—Us: k'nimióg'nen(-ep); *k'nimiog'wínen(ep).*
He-She—You: k'nimióg'wu (-ep); *k'nimiog'wíwu (-p).*
He-She—Them (An.): **Indef.** w'nimía; *w'nimiawíwu.* **Def.** w'nimíuk; **P:** w'nimiápenik; *w'nimiawíwuk;* **P:** *w'nimiawiwápenik.*
He-She—Them (Inan.): w'nimí'ton'l; **P:** w'nimi'tonép'n; *w'nimi'tówunul;* **P:** *w'nimi'towunépenil.*

We (Incl.)—Thee: k'nimiólp'n (-opus); *k'nimiolóp'n;* **P:** *k'nimiolopóp'n (-us),* but note k'pechíptolnén(-ep) = **Def.** 'we bring it to thee'; *k'pechiptolónen(-ep).*
We (Incl.)—Him-Her: **Indef.** k'nimiáp'n (-ep): *k'nimiawíp'n(-ep).* **Def.** k'nimiánen (-ep); *k'nimiawínen (-ep)*; k'nimianna; *k'nimiawinna.*
We (Incl.)—It: **Indef.** k'nimi'tonép'n(-ep); *k'nimi'towíp'n (-ep).* **Def.** k'nimí'tonén (-ep); *k'nimí'towinén (-ep).*

[4] The element *-h-* is a connecting consonant here.
[5] The *n*-form, really participial, is often definite; see note 9 below.

We (Incl.)—You:[6] k'nimiólp'n (-ep and -opus); *k'nimiolóp'n;* **P:** *k'nimiolopóp'n.* This form has a similar dative combination to that in **We (Incl.)—Thee** above, i. e., k'—olnen; *k'—olonen.*

We (Incl.)—Them (An.): Indef. and **Def.**[7] k'nimiánnawa; **P:** k'nimiannawápenik; *k'nimiawínnawa;* **P:** *k'nimiawinnawápenik.* **Def.** k'nimiánnawuk; **P:** k'nimiannawépenik; *k'nimiawínnawuk;* **P:** *k'nimiawinnawépenik.*

We (Incl.)—Them (Inan.): k'nimi'tonénwul; **P:** k'nimi'tonenépenil; *k'nimi'towinén'wul;* **P:** *k'nimi'towinenépenil.*

We (Excl.)—Thee, Him-Her, etc., differs from the above forms only by the n-preformative instead of the k'.

You—Me:[4] k'nimi-h-í'pa; *k'nimi-h-iwí'pa.*

You—Him-Her: Indef. k'nimiá'pa (-p); *k'nimiawí'pa (-p).* **Def.** k'nimiáwa (-p'n); *k'nimiawíwa(-pn).*

You—It (Indef.): k'nimitó'pa(-p'n); *k'nimitowí'pa(-p'n).* **Def.** k'nimitónia; **P:** k'nimitoniáspenil; *k'nimi'towúno;* **P:** *k'nimi'towiwáspenil.*

You—Us:[4] k'nimi-h-íp'n (-ep; epus); *k'nimiyawíp'n(-ep; epus).*

You—Them (An.): Indef. k'nimiánia; *k'nimiawiyania.* **Def.** k'nimiáwa; **P:** k'nimiawépenik;[7] *k'nimiawíwu;* **P:** *k'nimiawiwépenik.*

You—Them (Inan.): Indef. k'nimi'tónia; *k'nimi'towúno;* **P:** k'nimi'tonépenil; *k'nimi'ton'wiwépenil.* **Def.** k'nimi'ton'wul; *k'nimi'towún'wul.*

They—Me: nimióguk; **P:** nimiogópenik;[8] *nimiog'wíwuk;* **P:** *nimiog'wiwépenik.*

They—Thee: k'nimióguk; **P:** k'nimiogópenik; *k'nimiog'wíwuk;* **P:** *k'nimiog'wiwépenik.*

[6] Note that **We-Thee** is identical with **We-You,** no distinction being made here between the singular and plural object. But cf. **They-Thee** and **They-You,** where the distinction is made!

[7] Note the apparently arbitrary difference in vowel in the past: *-wápenik* for the **Indef.** and *-wépenik* for the **Def.** Observe that *k'nimiánnawa* is used both with indefinite and definite nouns. When the noun is not expressed *k'nimiánnawuk* is used.

[8] The *o* in *-ópenik* is plainly due to vowel harmony from the *ō* inherent in *nimiōguk,* but note the *ō* in *w'nimi'towiwōpenik,* 'they do not see it,' where the *o*-vowel seems to be due to assimilation to the negative *w.*

They—Him-Her: **Indef.** w'nimiánia; **P:** w'nimiápenik; *w'nimiawiyánia;* **P:** *w'nimiawiwápenik.* **Def.** w'nimiáwul; **P:** w'nimiawápenik; *w'nimiawíwul;* **P:** *w'nimiawiwápenik.*

They—It: **Indef.** w'nimí'towuk; **P:** w'nimi'tópenik; *w'nimi'towíwuk;* **P:** *w'nimi'towiwópenik;*[8] **Def.** w'nimi'tónia; **P:** w'nimi'toniápenil; *w'nimi'towúno;* **P:** *w'nimi'towuniápenil.*

They—Us: k'nimióg'n'wuk; **P:** k'nimióg'nópenik; *k'nimiog'wín'wuk; k'nimiog'wiwápenik.*

They—You: k'nimióg'wuk; **P:** k'nimiogópenik; *k'nimiogowíwuk;* **P:** *k'nimiogowiwépenik.*

They—Them (An.): **Indef.** w'nimiánia; **P:** w'nimiawápenik; *w'nimiawawiyánia;* **P:** *w'nimiawiwápenik.* **Def.** w'nimiáwa or -wul; **P:** w'nimiawépenik; *w'nimiawíwu* or *-wul;* **P:** *w'nimiawiwápenik.*

They—Them (Inan.): **Indef.** w'nimi'tónia; **P:** w'nimi'toniápenil (-aspenil); *w'nimi'towúno;* **P:** *w'nimi'towuniápenil (-aspenil).* **Def.** w'nimi'tón'wul; *w'nimi'towún'wul;* **P:** w'nimi'tonwépenil; *w'nimi'towunépenil.*

Participial Forms.*

I—Thee: nimíolún; táyowe k'nimíol; *nimiólowun; tayowe k'nimiólo.*

I—Him-Her: nimían; táyowe nimía; *nimiawíwun; táyowe nimiáwi.*

I—It: nimí'toan; táyowe nimí'to(n);[9] *nimi'towíwun; tayowe nimi'towi.*

[9] The *n*-form seems to be optional.

I—You: táyowe k'nimólpa; *táyowe k'nimioló'pa.*

I—Them (An.): táyowe nimíuk; *táyowe nimiawíwuk.*

I—Them (Inan.): nimí'toanul; *nimi'towíwanul.*

Thou—Me: nimihíyin; *nimihiwíyin.*

* These forms are used in subordinate as well as in hanging clauses; thus, *nimiolun*, '(when) I see thee,' is also expressed by the finite construction, *tāyowe k'nimíol.* In many instances the purely participial form seems to be lacking, as in **I-You, I-Them,** etc. I believe, however, that there are participial forms for all the combinations; possibly forms which my Indian informant did not happen to think of at the moment. In the kindred Canadian Abenaki, it is possible to place purely participial forms for all almost all the possible phrases (Prince, *Miscellanea Linguistica in Onore di Graziodio Ascoli*, p. 358, Ascoli Memorial).

Thou—Him-Her: k'nimíyas;[10] nimían; *nimiawíyan.*
Thou—It: k'nimitoánes;[11] nimi'toan; *nimi'towíwun.*
Thou—Us: k'nimiyápenus;[11] nimiyáp'n; *nimiawíp'n.*
Thou—Them (An.): k'nimíuk; nimían(?);[9] *nimiwíyan.*
Thou—Them (Inan.): nimí'toanul; *nimí'towiwánul.*

He-She—Me: nimíhit; *nimihikw.*
He-She—Thee: k'nimíog:[12] *k'nimióg'wi.*
He-She—Him-Her: táyowe w'nimíal; nimiá'tit; *nimiyakw.*
He-She—It: nimi'toan; *nimi'towiwun.*
He-She—Us: táyowe k'nimióg'nen; *k'nimiog'wínen.*
He-She—You: táyowe k'nimióg'wu; *k'nimiog'wíwu.*
He-She—Them (An.): w'nimiá'tit;[13] *w'nimia'tíkw(?).*
He-She—Them (Inan.): táyowe w'nimí'towul; *w'nimi'towiwul.*

We—Thee: táyowe k'nimiólp'n; *táyowe k'nimiolóp'n (-ópus).*
We—Him: táyowe k'nimiánen or k'nimiáp'n; *táyowe k'nimiawíp'n; nimiyáwin(-us).*
We—It: táyowe k'nimí'tonen; *táyowe k'nimi'towínen; nimi'tow'-néwin(-us).*
We—You: táyowe k'nimiólp'n; *táyowe k'nimiolóp'n(opus).*
We—Them (An.): táyowe k'nimiánnawuk; *táyowe nimiáwan(-ós-penik).*
We—Them (Inan.): táyowe k'nimi'tonénwul; *táyowe nimi'tow'-néwin(-óspenil).*

You—Him-Her: táyowe kílwau k'nimiyáwa; *táyowe k'nimiyawíwa.*
You—Him-Her: táyowe kílwau k'nimiyáwa; *táyowe k'nimiyáwiwa.*

[10] The ending *-s* is common in the past (cf. **We-Them,** participle) and may often be substituted for the characteristic *-p,* or even combined with it, as *-pus* (**We-Thee; We-You**). I suspect that *k'nimíyas, k'nimi'toánes, k'nimi-yápenus* are really past forms here; i. e., that my informant understood the English 'see' in the past sense, following the New England dialect of English where 'see' = 'saw.' The *nimían*-form, which is purely participial, seems to be indeterminate, as it means 'I seeing him,' 'thou seeing him, them.' This is also the case with Abenaki *namihoan, namitoan.*

[11] Finite forms; *nimi'toan* and *nimiyáp'n* are the real participles.

[12] Note absence of the finite *-n*; *k'nimiōg'n,* 'he sees thee.'

[13] It is strange to find the *w*-prefix before a participial form; cf. **They-Them** in this list.

You—It: táyowe k'nimi'tónia; *tayowe k'nimi'ton* (*-iaspenil*);[14] *sic!*
You—Us: tayowe k'nimihíp'n; *tayowe k'nimiawíp'n.*
You—Them: nimiówuk; *nimiowíwuk.*
You—Them (Inan.): táyowe k'nimi'tónia; *táyowe k'nimi'towúnwul.*

They—Me: nimihiyóguk;[15] *nimihiog'wíwuk.*
They—Thee: táyowe k'nimióguk: *táyowe k'nimiog'wíwuk.*
They—Him: táyowe w'nimiáwul; *táyowe w'nimiawíwul.*
They—It: táyowe w'nimi'tónia; *táyowe w'nimi'towúno.*
They—Us: táyowe k'nimióg'n'wuk; *táyowe k'nimiog'n'wín'wuk.*
They—You: táyowe k'nimióg'wuk; *tayowe k'nimiogowíwuk.*
They—Them (An.): táyowe w'nimia'títit[13] or nimiá'tit; *táyowe w'nimiawíwu.*
They—Them (Inan.): táyowe w'nimia'tótit; *tayowe w'nimi'towún'-wul.*

Passive.

'I am seen,' nimióguk (='they see me'); (*katama*) *nimiog'wíwuk.*
'Thou art seen,' k'nimíuk;[16] (*katama*) *k'nimiokiū.*
'He is seen,' w'n'míkw'so; (*katama*) *w'nimikw'siū.*
'We are seen,' k'nimiokép'n; (*katama*) *k'nimiokép'n.*[17]
'You are seen,' k'nimioképa; (*katama*) *k'nimioképa.*
'They are seen,' nimíkw's'wuk; (*katama*) *nimikw'siwíyik.*

'To Have' (an. object sing.).

'I have,' nt-i-wa (-p);[18] *nt-i-yiwáwiw* (*-wip'n*).
'Thou hast,' k't-i-wa (-p); *k't-iyiwáwiw* (*-wip'n*).
'He has,' w't-i-wul; **P:** w't-i-wap'n or w't-wáspenil; *w't-i-wawíwul;* **P:** *w't-i-wawíp'n;* but w't-i-yowan, 'he has them.'
'We (Incl.) have,' k't-i-wáp'n (-ep); *k't-i-yiwawíp'n* (*-ep*).
'You have,' k't-i-wá (-pn); *k't-i-yiwáwina* (*-p'n*).

[14] This can hardly be correct as a negative form. It seems to be a past form, owing to the *-s-* in *-áspenil.*

[15] Apparently a pure participial formation. The finite form 'they see me' = *nimióguk.*

[16] Apparently a pure passive. Note the finite *k'nimióguk,* 'they see thee.'

[17] It is strange to find no distinctively negative form here.

[18] Probably should be *nt-i-wap'n, kt-i-wap'n* in the past.

'They have,' **Indef.** w't-i-yánia; **P:** w't-i-yápenik; *w't-i-yiyawiyánia.*
Def. w't-i-yáwul; **P:** w't-iyawáp'n; *w't-iyawiwul.*

'TO HAVE' (INAN. OBJECT ALSO = 'TO BE').

n't-í-yin (-es; -ep'n).
k't-i-yin (-es; -ep'n).
w't-í-yin (-es; -ep'n).
k't-i-yíp'n (-es; -ep'n).
k't-i-yí'pa (-es; -ep'n).
w't-i-yínia; **P:** w't-i-yipenik.
w't-í-wul; **P:** w't-i-yipenil.

IRREGULAR ELEMENTS OF "TO HAVE" AND "TO BE."

Third Person Singular: al-ech, 'let it be'; el-e-sin,[19] 'where he is'; eyik, 'he (really 'it') is'; eyit, 'where he is'; el-eyit, 'where he is'; el-i-y-ijil = obviative of eyit; eyin, 'it being'; meskw nit el-i-nook, 'before this is so' (neg.);[20] tan ot'l-i-yin,[21] 'however it may be'; ch'wi-l-eyo, 'it must be'; w't-ach'wi-t-iwal, 'he must have it'; kis-iyit,[22] 'it having been'; w'-kichiyawi-wanyogonia, 'they have enough of it.'

Third Person Plural: m'si ayale, 'all who are'; eyoltitit, 'they being' (reflex.) eli-y-oltitit, 'as they are' (reflex.); el-igek, 'they who are'; etutek, 'they being'; eyilit; obv. eyilijil, 'where they are'; iakw, 'where they are'; weji-ya-witits, 'where they were' (with -s = Past).

SCHEME OF VERBAL PREFIXES AND SUFFIXES.

	ME.	THEE.	HIM-HER.	IT.
I		k—ol, -el (-en)	n—a, u	* n—to
		k—olo	*n—awi*	* *n—towi*
				n—ton
				n—towun

[19] Note *e* for *i* in *el-e-sin, ĕyik, ĕyit,* due to vowel harmony.
'he has taught me.'

[20] *Meskw,* which is used in the sense 'before,' really means 'not yet,' and therefore takes the negative verb.

[21] Note the phonetic *l* before the vowel root and the connecting *-t-* between the prefix and the *l.*

[22] *Kis,* 'already,' is the sign of the perfect tense; thus, *nkis-ake'kimkon,* 'he taught me.'

Thou	k—i *k—iwi*		k—a, u *k—awi*	* k—to * *k—towi* k—ton *k—towun*
He-She	n—gon, g'n *n—g'wi*	k—gon, g'n *k—g'wi*	*w'—a (n) **w—awi* w—al *w—awiwul*	*w—to **w—towi* w—ton *w—towun*
We (Incl.)		*k—olp'n **k—olop'n* **k—olnen *k—olonen*	* k—ap'n * *k—awip'n* ** k—anen, anna *k—awinen, awinna*	* k—tonep'n * *k—towip'n* k—tonen *k—towinen*
We (Excl.)		*n—olp'n **n—olop'n* **n—olnen *n—olonen*	* n—ap'n * *n—awip'n* n—anen, anna *n—awinen, awinna*	* n—tonep'n * *n—towip'n* n—tonen *n—towinen*
You	k—i'pa *k—iwi'pa*		* k—a'pa * *k—awi'pa* k—awa, u *k—awiwa (u)*	* k—to'pa * *k—towi'pa* k—tonia *k—towuno*
They	n—oguk *n—og'wiwuk*	k—oguk *k—og'wiwuk*	*w—ania **w—awiyania* w—wul *w—awiwul*	*w—towuk **w—towiwuk* w—tonia *w—towuno*

	Us.	You.	Them (An.).	Them (Inan.).
I		k—olpa *k—olo'pa*	* n—a, u * *n—awiwu* n—uk *n—awiwuk*	*** n—ton'l *n—towun'l*
Thou	k—ap'n *k—awip'n*		* k—a, u * *k—awiwu* k—uk *k—awiwuk*	* k—tonia * *k—towuno* k—ton'l *k—towun'l*
He-She	k—og'nen *k—og'winen*	k—og'wu *k—og'wiwu*	*w—a, u **w—awiwu* w—uk *w—awiwuk*	***w—ton'l *w—towun'l*

We (Incl.)		k—olp'n *k—olop'n* **k—olnen ** *k—olonen*	* k—annawa * *k—awinnawa* k—annawuk *k—awinnawuk*	*** k—tonen'wul *k—towinen'wul*
We (Excl.)		*n—olp'n * *n—olop'n* **n—olnen ** *n—olonen*	* n—annawa * *n—awinnawa* n—annawuk *n—awinnawuk*	*** n—tonen'wul *n—towinen'wul*
You	k—ip'n *k—awip'n*		* k—ania or * k—awa *k—awiwiyania* k—awu *k—awiwu*	* k—tonia * *k—towuno* k—ton'wul *k—ton'wun'wul*
They	k—og'n'wuk *k—og'win'wuk*	k—og'wuk *k—og'wiwuk*	*w—ania * *w—awiyania* w—awa, u *w—awiwul*	*w—tonia * *w—towuno* w—ton'wul *w—towun'wul*

A study of the above forms will indicate that the main points of difference between the indefinite and definite combinations lie in the third person singular and throughout the plural. Although, as pointed out above, there is really only one tense, the present, there are certain endings which may be affixed to denote the past relation and the conditional-subjunctive. Thus, the *-p, -ep, p'n* and *-s*-elements are used for the past and conditional-subjunctive alike, and even appear in combination together, as *p's; ep's; op's.* A careful distinction must be made between the past-conditional *-p'n* and the *-p'n* of the first person plural as seen in **Thou—Us** and also in the intransitive verb as given above.

There is also, as shown, a passive voice, the distinctive element of which is *-k, -s* and in combination *-kw's.* Note also the passive forms *m'skówa,* 'he will be found'; *w'metapéksin,* 'it is finished'; *milkónia wásis'l,* 'they are given to the child'; *weswéphogónia,* 'that they be taken back'; *nōtakw'siánp'n,* 'I was heard' (*nōt-*); *kitwitasso,* 'it is called.' Sometimes a reflexive is used for a passive: *elokélit,* 'what was done.' The reflexive, not indicated in the paradigms, is expressed in various ways; *e. g.,* by an *l-,* insert: *w'm'tyayew'lít-el-ín,* 'as if they were playing together'; *kinw-el-úswiū,* 'it shows itself'; *nt'lī-kisi-kwálp-el-es,* 'I will change myself,; *mache-*

kaú-d-il-it, 'as soon as they have gone off together,' etc. Motion is expressed by *pech-: 'pechiyan,* 'when I come'; *w'p'chitakan,* 'he sends him'; *pechi-pawatmat,* 'he is always desirous'; *pechipha,* 'he brings him,' etc.

'Must' is expressed by the insert *ach'wi: w't-ách'wi-sakitón'l,* 'he must rule'; and in the future: *k̂'t-ách'wi-t'lî-wíchiy'n,* 'thou shalt be (*t'li-*) compelled to take heart.'

Desire is indicated by *ktî-: w'k'tî-nimíal,* 'he wishes to see him'; *k'tî-eló'kelít,* 'what he wishes to do.'

There are many other such particles too numerous to mention in an article of this length.

As in all other Algonquin idioms, in the combined forms, the second person always takes precedence over the first and the first person over the third. Thus, in the forms *k'nimíol,* 'I see thee,' where the second person is the object and in *k'nimiáp'n,* 'you see me,' where the second person is the subject, the second personal element comes first. In such forms, however, as *nimía,* 'I see him'; *nimí'to,* 'I see it,' the first person appears in the first place.

The sign of the negative is the infixed *u*-vowel which, as shown above, frequently appears as *o* and often as *w*.

The use of the participle is most varied. Thus, it may take the place of the relative form as *nit pawálkwak,* 'this is what is wanted' (passive indicated by *-kw*), or it may be used to denote the action of the verb governed by a preposition *wechi-nimíolun,* 'in order for me to see thee,' or else it may be employed as a conditional: 'if' or 'when I see thee' = *nimíolun.* The negation of the participle is formed in the same way as the negative of the finite forms, *viz.,* by infixation of *u, o, w.*

Any noun may be verbalized by the ending *e-: w'skitáp-e,* 'he is a man'; by *-ewi: tan etúchi w'skitápewi,* 'so long as he is a man'; by *-ewiū: w'skitápewíū,* 'he becomes a man'; also by participial endings: *w'skitápewít,* 'he who is a man'; or by *-(w)eleso: w'skitápe-wéleso,* 'he becomes a man.'

Practically all the Passamaquoddy verbs are conjugated after the above model, most of the minor variations which occur being due to phonetic peculiarities.

NUMERALS.

The numerals up to five present three forms; *viz.*, a form used chiefly in counting, and adjectival animate and inanimate forms, as indicated by the following list. There is no trace of peculiar numerals used only with certain classes of substantive, as, for example, with round objects, etc., such as occur in Ojibwe.

	In Counting.	Animates.	Inanimates.
one	*nekw't*	*peskw;* obv. *-'l* *peskw* 'one, each' occasionally: *nekw't*	*peskw* occasionally: *nekw't*
two	*tábū*	*nīswuk* obv.: *nīsō*	*nīsn'l*
three	*sist*	*nówuk* obv.: *nōhō*	*nów'n'l*
four	*néu*	*néwuk* obv.: *nēwō*	*néw'n'l*
five	*nán*	*nán'w'k* obv.: *nānō*	*nán'w'l*
six	*kamáchin*	*kamáchin-keswuk* obv. *-kesō*	*kamáchin-kesn'l*
seven	*'lwîk'n'k*	*'lwĭk'n'k-keswuk* obv. *-kesō*	*'lwîk'n'k-kesn'l*
eight	*'km''lchin*	*'km''lchin-keswuk* obv. *-kesō*	*'k''mlchin-kesn'l*
nine	*eskw'nátek*	*eskw'nátek-keswuk* obv. *-kesō*	*eskw'nátek-kesn'l*
ten	*m'tul'n*	*m'tul'n-keswuk* obv. *-kesō*	*m'tuln'-kesn'l*

From eleven to fifteen, the numerals are formed from the tens by affixing for the animate and inanimate *-ankoso-wuk;* obv. *ankoso; ankosow'l,* respectively: *nisánkosowuk skitayik,* 'twelve men'; *nsánkoso-wuk* (obv. *-wo*); inan. *-w'l,* 'thirteen'; *newánko-,* 'fourteen,; *nananko,* 'fifteen.' From sixteen to nineteen the affixed element is *-kesánko: kamáchin-kesánkosowuk* (obv. *-kesánkoso*)*;* inan. *-kesánkosow'l,* etc.

From twenty on, the cardinal elements are as follows: *nisínsk-,* 'twenty'; *nsínsk-,* 'thirty'; *nēowinsk-,* 'forty'; *nanínsk-,* 'fifty'; *kamáchin-kesínsk-,* 'sixty'; *'lwîk'n-kesínsk,* 'seventy'; *'km''lchin-kesínsk,* 'eighty'; *eskw'nátek-kesínsk,* 'ninety'; *nekw'tát'kw-,* 'hun-

dred.' The animate and inanimate plurals are made from these forms by affixing the element; animate *-ke'kw'sowuk* (obv. *-ke-'kw'so*)*; inan. -ke'kw'-sow'l;* as *nēowínsk-ke'kw'sowuk skitápyik,* 'forty men,' etc.

The ordinals, with the exception of *amsk'was,* 'first,' are formed from the cardinals by adding *-ewéi* (*nisewéi,* 'second'; *nōwewéi,* 'third,' etc.), until tenth which is *nekw'tinskewéi.* To the element *-anko* of the -teens is added the ending *-wewei; nēowánkowewéi,* 'fourteenth,' and to the ending *-insk* is added *-ekewei;* as *nisinske-kewéi,* 'twentieth.'

The numerals are usually inflected adjectivally preceding their substantives, but they may be used indeclinably, as *eskw'nátek-kesōk'niū,* 'nine days.'

The following love-song will serve to illustrate both the present musical style of the tribe, which is undoubtedly influenced by the Roman Catholic Gregorian chants of their missionary priests, and also the construction of the language. It should be noted that the last syllable *û* of the song must be prolonged as much as possible, and finally allowed to end with a rapid expulsion of the breath, this is the so-called "die-away" which is a characteristic of much of the American music.

Peskî k't-el-ápin elmî-nelemwík
Lonely thou lookest up-stream
Elmî-sîkwak-lo takwâk'nwi-lok-lo
In spring and in autumn;
Chîptuk k'nimihi-sa kwilakweyún
Perhaps thou mayest see me seeking thee.
Kuwēnodîn Û; kuwēnodin Û.
It is long O; It is long O!


Pes - kî k'te - la - pin el - mî -
ne - lem-wik; el - mî - sî-kwak-
lō ta-kwa-k'n - wi-lok-lō chip-
tuk ke-ni-mi - hî - sa kwi - la-kwe-yun
ku - wê - no - din
u ku - we - - no - din u

Commentary.

In the above song, ***peskî*** is adverbial from *peskw,* 'one; lonely'; ***k't-el-apin:*** ***k*** = second person + the infixed *-t-* before a vowel + ***el,*** the element of prolongation, 'thou art doing it' + ***ap,*** 'look' + the intransitive ***in,*** seen above in the conjugation of ***kwaskw,*** 'run'; ***elmî-nelemwik:*** ***elmî*** = 'being; while there' + ***nelemwik,*** which also occurs in the form ***nul'muk,*** showing the indeterminate vowel = 'up' —here probably 'up-stream'; *elmî-sikwak-lo: elmî,* here, = 'during' + ***sîkwak,*** a musical prolongation of *sîkw'k,* 'in spring' + *lō,* the asseverative particle; ***takwâk'nwi-lok-lo:*** *takwâk'n,* 'autumn,' + the adjectival *-wi* + the verbal inan. *-lok* + the asseverative *-lo;* ***chîp-tuk,*** probably contains the same element as the future *-ch* + the verbal ***p't*** + the inan. participle *-uk* = 'when it may be'; ***k'nimi-hí-sa,*** 'thou seest me' with the conditional *-sa;* ***kwilakwiyun:*** ***kwil,*** 'seek,' + the formative *ak* + *(w)iyun,* participial, = **I — Thee;** ***kuwēnodin*** *U:* ***kwēn,*** 'be long,' + the intransive endings -(*o*)*din* + the exclamation *U* = 'Oh.'

DISCUSSION OF "A KINETIC THEORY OF GRAVITATION."

(PLATE I.)

By CHARLES F. BRUSH.

(*Read April 24, 1914.*)

1. GRAVITATION IS DUE TO INTRINSIC ENERGY OF THE ETHER.

At the Minneapolis meeting of the American Association for the Advancement of Science I had the honor to outline "A Kinetic Theory of Gravitation,"[1] which is in substance briefly as follows:

The ether is assumed to be endowed with vast intrinsic kinetic energy in wave form of some sort capable of motive action on particles, atoms or molecules of matter, and propagated in every conceivable direction so that the wave energy is isotropic. The waves are of such low frequency, or otherwise of such character, that they pass through all bodies without obstruction other than that concerned in gravitation. Distribution of the ether's energy is uniform throughout the universe except as modified by the presence of matter.

Atoms or particles are imagined to be continually buffeted in all directions by the ether waves like particles of a precipitate suspended in turbulent water. There are no collisions because neighboring particles follow very nearly parallel paths.

Each particle or atom of matter is regarded as a center of activity due to its energy of translation initially derived from the ether. There is continual absorption and restitution of the ether's energy, normally equal in amount; but the ether is permanently robbed of as much of its energy as is represented by the mean kinetic energy of the particle or atom. The particle or atom thus has a field of influence extending in all directions, or casts a spherical energy shadow, so to speak, the depth or density of the shadow varying with the inverse square of distance. The energy shadow of a body of matter

[1] *Science*, March 10, 1911; *Nature*, March 23, 1911.

is the sum of the shadows of its constituent parts. The energy shadows of two gravitating bodies interblend, so that the energy density between them is less than elsewhere, and they are pushed toward each other by the superior energy density, or wave pressure, on the sides turned away from each other.

That the ether really *is* endowed with vast intrinsic energy in some form or forms is the belief of many eminent physicists, and it seems to me highly probable that *all* energy has its source and destination in the ether; that is to say, that energy in all the various forms in which we observe it, comes in some way from the ether and is energy *of* the ether. This view does not in any manner conflict with the principle of conservation of energy.

In support of my contention that etherial energy is the cause and essence of gravitation, I wish to emphasize particularly, what seems to me an obvious fact, that the energy acquired by a falling body comes from the ether, and is restored to the ether when that body undergoes negative gravitational acceleration.

In this connection I cannot do better than quote Lord Kelvin's description of the collision of two very large bodies through the influence of gravitation. In his "Popular Lectures and Addresses" (Vol. 1, 413–417) he says:

"To fix the ideas think of two cool solid globes, each of the same mean density as the earth and half the sun's diameter, given at rest, or nearly at rest, at a distance asunder equal to twice the earth's distance from the sun. They will fall together and collide in exactly half a year. The collision will last for about half an hour, in the course of which they will be transformed into a violently agitated incandescent fluid mass flying outward from the line of motion before the collision and swelling to a bulk several times greater than the sum of the original bulks of the two globes. . . . The time of flying out would probably be less than half a year when the fluid mass must begin to fall in again towards the axis. In something less than a year after the first collision the fluid will again be in a state of maximum crowding towards the center, and this time even more violently agitated than it was immediately after the first collision; and it will again fly outward, but this time axially towards the places whence the two globes fell. It will again fall inwards, and

after a rapidly subsiding series of quicker and quicker oscillations it will subside, probably in the course of two or three years, into a globular star of about the same mass, heat and brightness as our present sun."

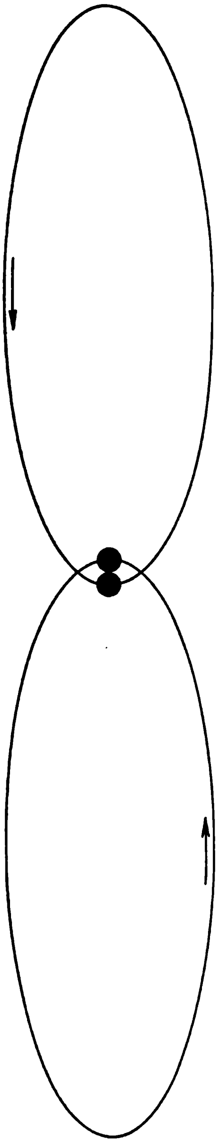


FIG. 1.

Undoubtedly this is a substantially correct description of what would happen under the conditions named. The two cold bodies would acquire *from some source external to themselves* the vast energy represented by the heat of the sun, heat sufficient to maintain the enormous solar radiation millions of years without sensible diminution. And this vast accumulation of energy would occur in half a year, largely in the *last few days* before collision. There is, to me, no conceivable source of this energy other than the ether. It may be argued that the two cold bodies, as a gravitating system, initially possessed all this energy in the form of "potential energy of position." This is a most convenient expression, but it affords no explanation of the *source* of the energy until, as I pointed out at the Washington meeting, we take the energy-endowed ether into partnership as an essential part of the system. Certainly the energy could not be resident in the two cold motionless globes. For a homely illustration, think of two golf balls joined by a stretched thread of rubber; they form an attracting system and possess "potential energy of position" or separation, but the energy does not reside in the balls, it is in the stretched rubber thread.

Later in his description Lord Kelvin says: "If, instead of being at rest initially, . . . each globe had a transverse velocity of three quarters (or anything more than .71) of a kilometer per second, they would just escape collision, and would revolve in ellipses

round their common center of inertia in a period of one year, just grazing each other's surface every time they came to the nearest points of their orbits." (Assuming of course that the globes were sufficiently rigid to escape disruption by tidal forces.)

To aid in forming a mental picture of this last case described by Lord Kelvin, in which the two globes fall together but do not collide, I have made a diagram (Fig. 1) of the two elliptical orbits; and in order to show the globes of appreciable size, the orbits are made very much less excentric than Kelvin's premises call for. The globes are shown at perihelion, just escaping collision. Of course, the globes in falling from aphelion to perihelion would gather the same amount of energy that they did in the case of collision, where their motion was arrested and their kinetic energy was thus converted into heat; but without collision the vast energy acquired during positive acceleration from aphelion to perihelion would disappear during negative acceleration from perihelion to aphelion, and be transformed back to the ether whence it came.

The sun and planets of the solar system, and the planets and their satellites, because of the excentricity of their orbits, continually go through the same kind of cycle described by Lord Kelvin, differing from that only in degree. For instance, the earth in its six months' passage from aphelion to perihelion falls about three million miles toward the sun, and gains in orbital velocity about five eighths of a mile per second. It thus acquires new kinetic energy from the ether which, if it could be manifested as heat, would be sufficient to evaporate all the oceans, lakes, and rivers, heat the dry earth to vivid incandescence, and vaporize much of it; the earth would become a miniature sun. And all this energy is restored to the ether during the next half year while the earth is moving from perihelion to aphelion.

With the idea in mind that a falling body gathers energy from the ether, and restores all of it to the ether when raised the same distance against gravitation, *by any means,* homely examples are at once suggested; thus, a stone thrown upward and falling again, does it in the reverse order, and a common clock pendulum goes through, and repeats the cycle with almost the regularity of a sun and planet.

In the theory of gravitation under discussion, the only new postu-

late is that some or much of the ether's intrinsic energy is *kinetic* and consists of some sort of wave motion or energy flux, whereby a disturbance at any point in the free ether is ultimately felt everywhere else, diminishing in intensity, of course, with the inverse square of distance from the seat of disturbance.

It is not difficult to conceive of kinetic energy in the ether quite apart from matter. Radiation is one form of such energy, and when once launched in the ether it is persistent and quite independent of its source. Interstellar space is alive with wave energy radiated from countless suns, and at points far removed from any single sun this energy is approximately isotropic. Of course this known isotropic wave energy in the ether of space is far too feeble to play any appreciable part in gravitation, and I call attention to it only for the purpose of showing that one sort of free isotropic wave energy in or of the ether in celestial space is already a known phenomenon.

Probably the ether waves concerned in gravitation are not the transverse kind known to us, though it is not difficult to think of transverse waves of great amplitude, embodying great energy, and of such great length that they pass freely through all bodies without appreciably heating them—even electrical conductors. (Incidentally, we cannot be sure that the intrinsic energy of the ether does not impart some low degree of temperature to matter, because we know of nothing in nature at the absolute zero of temperature or anywhere near it.) It seems more likely, however, that the ether waves of gravitation are longitudinal, or otherwise consist in an energy flux which, by reason of its universal presence, has not been made manifest except by gravitation.

It is easy to understand how the supposed spherical field of influence, or energy shadow, surrounding any body of matter may be initiated, but just how it is maintained may never be known; though I hope to have something to say in this connection in a future discussion. But that the field of influence actually *is* maintained seems certain; gravitation itself is a demonstration of it.

The simplest mental picture of the supposed field of influence which I can think of is a spherical energy shadow, and I have endeavored to make this conception visible in Figs. 2 and 3 as light

Fig. 2

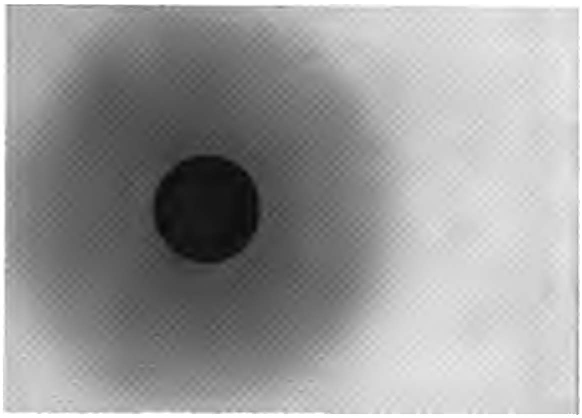


Fig. 3

shadows cast by black spheres. Of course the shadows as here represented are enormously exaggerated. Plate I., Fig. 2, represents a single sphere and the adjacent parts of its spherical shadow. (Obviously a body of *any* shape will cast a shadow substantially spherical.) Plate I., Fig. 3, shows two neighboring spheres with their shadows interblending. The greater depth of shadow between the spheres is clearly indicated, and it is into this deeper shadow that the two gravitating bodies are supposed to be pushed by the superior energy flux from right and left.

Some curious and interesting secondary phenomena are suggested by this conception of the mechanism of gravitation. One of these may be described as follows: Imagine two bodies, such as those of Fig. 1 or Plate I., Fig. 3, falling toward each other by reason of their mutual attraction. They are continually accelerating, and absorbing energy from the ether waves or energy flux pushing them toward each other, whereby these waves pass through and beyond each body *slightly depleted of their energy,* and thus offer less than normal resistance to the advance of the other body; that is to say, the energy shadow between the bodies, into which they are pushed, grows deeper and deeper as they approach, not only because of their lessening distance from each other, but also because of their increasingly rapid transformation of energy as they gain velocity. And it does not matter if the two attracting bodies differ greatly in mass, like the sun and a planet or the earth and a tennis ball, because they will equally acquire momentum, and each will affect the other in the manner described. Stated concisely this means, if my premises are tenable, that Newton's law of inverse squares is not rigidly true for *accelerating* bodies; but that for positively accelerating (approaching) bodies the force of attraction increases a little faster than the inverse square of distance. The force of attraction instead of varying as $1/D^2$ as it does for bodies at rest or in uniform motion, varies as $1/D^{(2-x)}$ for bodies accelerating in the line of attraction, wherein x is a very small quantity which appears to vary with the rate of energy transformation or velocity of fall. When acceleration is negative, that is to say, when energy transformation is *from* the accelerating body *to* the ether, x becomes positive.

Let us consider the effect of x on a planetary orbit: If the orbit is circular, $x=0$ because there is no change of velocity; but if the orbit is excentric, x obviously grows in value and importance with the excentricity, though always equaling zero at aphelion and perihelion. Fig. 4 illustrates the sun and a planet at aphelion in an ex-

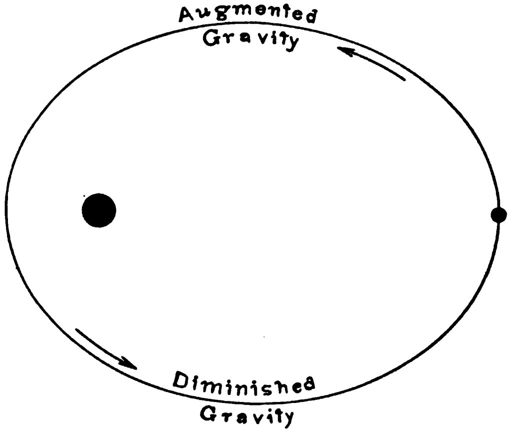


FIG. 4.

aggeratedly excentric orbit. As the planet moves from aphelion to perihelion, normal attraction between the sun and planet is augmented by the positive acceleration of both as before explained; and while the planet moves from perihelion to aphelion normal attraction is diminished by negative acceleration.

If I am not mistaken in my mechanics, the gravitational disturbance above described will slightly change the shape of the orbit, and cause a continual advance in the position of perihelion by advancing the line of apsides. Probably the effect is too small to be detected in the case of any of the planets of the solar system except perhaps Mercury, because of the small excentricity of their orbits; but the high excentricity of Mercury's orbit possibly may reveal it, and I hope it may be found adequate to account for some of the anomalious secular advance of the perihelion of Mercury's orbit. I shall be glad to have my astronomical friends investigate this.

The orbit of the moon is not very excentric, but she moves toward and away from the sun almost the full diameter of her orbit

every month. Perhaps the gravitational disturbance I have suggested may aid in explaining some of her more obscure motions; and I hope it will be found to have a slight accelerating tendency so as to compensate the slight retarding tendency of which I shall treat in the second division of this paper.

2. Transmission of Gravitation Cannot be Instantaneous.

Laplace at first sought to explain the secular acceleration of the moon's mean motion by ascribing to gravitation a finite velocity of propagation. Later he said:[2] "The time of its transmission, if it were sensible to us, would be particularly evinced in the acceleration of the moon's motion. I suggested this as a means of explaining the acceleration which is observed in this motion; and I have found that in order to satisfy observations we must ascribe to the force of gravity, a velocity seven millions of times greater than that of a ray of light. As the cause of the secular equation of the moon (c) is now well understood, we may affirm that the attraction is transmitted fifty millions of times more rapidly than light. We can therefore assume, without any apprehension of error, that its transmission is instantaneous."

I doubt if anyone who has bestowed careful thought on the subject, in the light of present-day physics, really believes this. To me, it is inconceivable that my change of position, as I walk across a room, is felt among the fixed stars while I am still walking; but the justly great name and fame of Laplace has stamped this dogma with the seal of authority, and for more than a century it has blocked the path of fruitful thought on the physics of gravitation.

Doubtless Laplace made no serious mathematical mistake in reaching his remarkable conclusion, but perhaps he erred in his choice of premises. He postulated[3] a "force" or "gravific fluid," "which rushes towards the sun with an immense rapidity; the resistance which the planet experiences from this current in the direction of the tangent, he conceives to produce a perturbation in the elliptic motion, like to the aberration of light." He then applied this

[2] "System of the World," Harte's translation, Vol. 2, p. 322.

[3] Harte's translation, Vol. 2, notes, p. 490.

conception to the case of the earth and moon. I have endeavored to visualize Laplace's conception in Fig. 5, in which E represents the earth, M the moon moving in the dotted line orbit in the direction indicated by the large arrow, and lines NE the "gravific fluid" rushing from all directions toward the earth. The orbital motion of the moon continually carries her laterally against the stream of "gravific

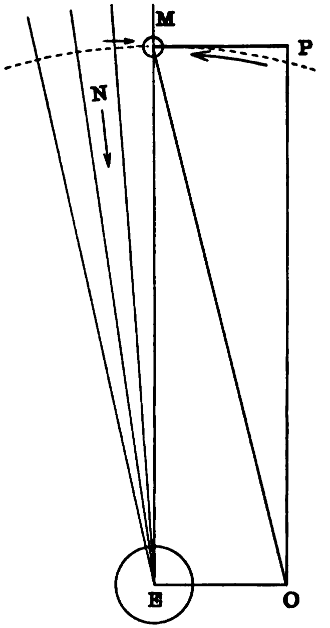


FIG. 5.

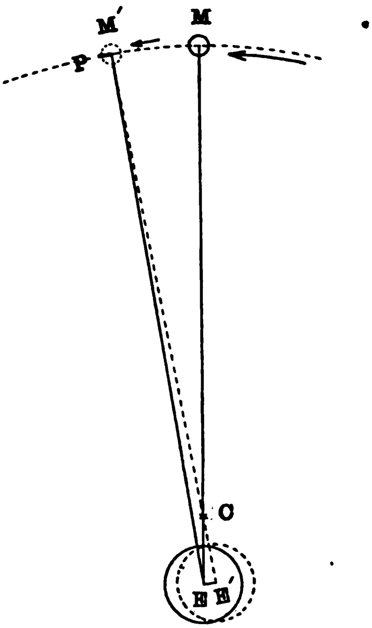


FIG. 6.

fluid," whereby she experiences a tangential retarding force, indicated by the small arrow, just as if a less rapid flow of "gravific fluid" came from that direction. Let the line MP represent the direction and value of the retarding force in terms of the centripetal force ME. Completing the parallelogram of forces, we find the line of the moon's attraction shifted from ME to MO. Clearly this would result in the moon taking an orbit in the form of a contracting spiral which would ultimately bring her to the earth. At the same time her actual velocity would continually increase (and her angular velocity still more so) because of her falling toward the

earth; gravity directly, and the retarding force indirectly conspiring toward this result. With the assumed velocity of light for the "gravific fluid," Laplace found that the angular acceleration of the moon's motion would be millions of times greater than necessary to account for her known acceleration.

I have thus outlined Laplace's conception of the mechanism of gravitation, which led to his famous conclusion of virtually infinite velocity of propagation, because I have not met with anything of the sort in modern text books of astronomy or physics; his startling conclusion is known to everyone, but his premises are generally forgotten; and further because I wish to have it clearly in mind for contrast with what is to follow.

Returning now to the theory of gravitation under discussion: In Fig. 6, E represents the earth and M the moon moving in the dotted line orbit in the direction indicated by the large arrow, both revolving about their common center of gravity C. Instead of showing C well inside the earth's circumference where it belongs, I have shown it outside, so as to enlarge certain details of the diagram and thus avoid confusion of lines.

The earth and moon are each supposed to cast a spherical energy shadow, or occupy the center of a spherical field of influence, as already indicated, into which the other is pushed by the slightly superior energy-flux coming from beyond it. The strongest push of each is toward the densest part or *origin* of the shadow of the other. Thus, if earth and moon were stationary, each would be pushed toward the center of mass of the other. But while the shadow, emanating so to speak, from the earth at any instant is being propagated outward to the moon's orbit, the latter will have moved to M', and the earth will have moved to E'. Clearly then, the moon at M' will not be pushed toward E', but toward E, which is the origin of the shadow into which it is being pushed. The centripetal force $M'E$ may be resolved into the radial component $M'E'$ and the tangential component $M'P$ equal to the displacement of the earth's center from E to E'. Clearly, the force $M'P$ is an *accelerating* force, and bears the same ratio to gravity at M' that $M'P$ bears to $M'E'$.

If the velocity of propagation of the energy shadow equals the

velocity of light, then the displacement of the earth's center from E to E' will be about 52 feet, and the tangential force $M'P$ will be about one twenty-four-millionth of gravity at the distance of the moon.

Obviously, this very small tangential force will tend to make the moon's orbit an expanding spiral of very small pitch; but the vastly greater force of gravity will resist this tendency and nearly, but not quite, counteract it; the net effect being an extremely slow lengthening of the radius vector, and a very slight *retardation* of real as well as angular velocity. This paradoxical effect, of an accelerating force producing an orbital retardation, is explained by Sir George H. Darwin in his chapter on tidal friction and the genesis of the moon.[4]

I have made only a very rough estimate of the secular retardation of the moon's mean motion which this minute accelerating force will bring about, with gravitational transmission taken equal to the velocity of light, but have satisfied myself that it will amount to a very few seconds of arc only, in a century; and I do not claim that the velocity of light is the velocity of gravitational propagation unless the postulated ether waves are ultimately found to be transverse like those of radiation. I think it probable that they are longitudinal, or otherwise different from those of radiation. If this be true, the velocity of propagation may be several times greater than that of light, and the secular retardation of the moon correspondingly less.

I realize that any uncompensated retardation of the moon's motion will add to the present outstanding observed acceleration, if any; but am hopeful that the slight departure from Newton's law of inverse squares already suggested may, in connection with other motions of the moon, supply some of the necessary compensation. There is also a minute source of compensation, due to motion through the ether, which I intend to consider in another discussion.

CLEVELAND,
April, 1914.

[4] "The Tides," Chap. XVI.

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THE AFFINITIES AND DISTRIBUTION OF THE LOWER EOCENE FLORA OF SOUTHEASTERN NORTH AMERICA.

BY EDWARD WILBER BERRY.

(Read April 25, 1914.)

INTRODUCTION.

Three years ago I made a preliminary announcement before this Society[1] concerning the fossil floras of southeastern North America. I have, in the interim, completed a monograph of the extensive and especially well preserved plants of the Lower Eocene, and it is some of the results of this detailed study that are given in the present communication. This work has been done under the auspices of the United States Geological Survey, to the director of which organization I am indebted for permission to publish the following preliminary abstract. I also wish to express my great indebtedness to Dr. T. Wayland Vaughan, who has had general charge of the Coastal Plain investigations and to whom great credit is due for their comprehensive character.

PHYSICAL CONDITIONS INDICATED BY THE FLORA.

There is no part of North America so favorably situated for the study of the floras which preceded the present, extending backward

[1] *Proc. Amer. Philos. Soc.*, Vol. 50, No. 199, 1911.

to a time which marks the first recorded appearance of angiosperms, as that of the South Atlantic and Gulf states. No single part of North America contains so continuous a series of Tertiary deposits carrying fossil plants. In this area are found abundant floras in the lower and middle stages of the Eocene, a small flora in the Upper Eocene, considerable floras in the Oligocene, some in the later Miocene, and rather abundant fossil plants in the Pliocene, as well as numerous Pleistocene deposits carrying fossil plants. The Rocky Mountain region is rich in Eocene fossil plants and there are some Miocene floras, but practically no Oligocene or Pliocene floras are known. The Pacific coast region likewise furnishes Eocene and Miocene fossil plants but none of Oligocene age.

The fossil floras of the Coastal Plain are found in an area where it is possible to attain to some measure of accuracy in predicating the general character and course of ocean currents and winds and other physical features of the environment. On the other hand the western floras just mentioned grew in areas where vulcanism was great at times; in areas of great orogenic activity, where changes in topography were numerous and elevations of several thousands of feet are recorded; areas in which climatic conditions not only varied from place to place, but passed through a large cycle of secular changes. All these factors greatly complicate the floral history.

The floras of the southern Coastal Plain are moreover checked for the most part by very abundant marine fauna in intercalated beds, or the plant-bearing beds which represent the coastal swamps and the shallow water deposition of the old embayment merge laterally with the contemporaneous limestones or marls which were forming in more open waters along the coasts to the southward, so that there is a considerable body of facts bearing on depth, character of the bottom, and marine temperatures, with which to compare land temperatures. These criteria have been admirably worked out for the Florida area by Doctors Dall and Vaughan for the post-Eocene and their results furnished a reliable datum plan for the deductions to be derived from the study of the fossil floras of those times.

With the exception of fragments of the petrified stems of conifers, palms and dicotyledons the plant-remains are in the form of impressions, mostly of foliage, but with a goodly representation

of fruits and seeds, and in some few cases even flowers are preserved.

While the oscillations of the embayment area have been numerous they have been, as I have just mentioned, inconsiderable in amount, only a few hundred feet at most, and the coastal region has uniformly been one of slight relief. The various floras show an almost complete absence of upland types. This is in striking contrast to the European older Tertiary floras. The only large area of the globe which has been thoroughly studied—Europe—was far less stable than this region in Tertiary times and lying much farther toward the pole was subsequently subjected to the rigors of Pleistocene conditions whose influence never reached our southern states.

The paleobotanical record of the Atlantic and Gulf Coastal Plain furnishes a history which extends back as I have just mentioned beyond the oldest known angiosperms to a time (Lower Cretaceous) when the flora was made up almost entirely of tree-ferns, conifers and those interesting cycadophytes (Cycadeoidea) whose trunks are sometimes preserved with such marvelous perfection that the outlines of the embryos in the ovules can often be made out in detail. Coming a step nearer my present theme, a step of some millions of years from the Lower into the Upper Cretaceous, we find the first great modernization of the floras of the world due to the seemingly sudden evolution of the main types of angiosperms. These Upper Cretaceous floras are well represented in the Coastal Plain from Marthas Vineyard to Texas. They extend northward to Greenland and southward to Argentina in South America, and are found to indicate very different physical conditions from those which prevail at the present time. I do not intend, however, to dwell upon the Upper Cretaceous floras in this connection but pass to a consideration of the succeeding Eocene epoch of plant evolution.

The Eocene as defined by Lyell was marked by the dawn of the recent species of marine mollusca. It is equally well marked by the sudden expansion and evolution of modern types of plants after a long antecedent Cretaceous development. The floras become thoroughly modernized as compared with those which preceded them, although they are still very different in their general facies and distribution from those of the present.

In the earliest epoch of the Eocene known as the Midway, the relations of sea and land in the Gulf area differed in only minor particulars from that of the late Cretaceous. The waters of the Mississippi Gulf were, however, deeper. This factor combined with a much less influx of fresh water from the tributary streams, due in some measure to the low relief of the land, enabled marine faunas to reach well toward the head of the gulf. These faunas indicate subtropical bottom temperatures northward as far as Paducah, Ky. The

FIG. 1. Sketch map showing the approximate position of the shore line, A–A, at the beginning of the Wilcox transgression and B–B the area covered by the Wilcox sea during its maximum transgression. C–C, the extreme northern limit of the Willcox flora under existing climatic conditions.

known floras are very scanty and unsatisfactory and in the present state of our knowledge do not merit an extended discussion. The maximum transgression of the sea during the Midway epoch is shown on the accompanying sketch map (Fig. 1).

The Midway Eocene was succeeded by a long interval during which the sea is believed to have withdrawn southward at least as far as the position indicated on the accompanying sketch map (Fig. 1, *A–A*), since terrestrial conditions are known at the extreme base

of the Wilcox in the most southerly areas of their outcrop. This interval of emergence of the embayment area was followed by an equally long interval during which a great thickness of deposits was laid down that are collectively known as the Wilcox group. The character of these sediments and their faunas show that the Mississippi gulf was somewhat restricted and much shallower than in the preceding epoch, with true marine conditions prevalent only in its lower portion. The shores were low and relatively flat. They were flanked by current- or wave-built bars and separated from the mainland by shallow inlets or lagoons. The lower courses of the streams were transformed into shallow estuaries or broad swamps through which the smaller streams meandered.

The maximum area covered or underlain by Wilcox deposits is also indicated on the accompanying sketch map (Fig. 1, *B–B*) which shows approximately the shore line along which the vegetation migrated. As has been already remarked the Wilcox deposits have yielded one of the most extensive of known fossil floras, an assemblage of extinct species which sheds considerable light on the physical conditions of the marginal lands of Wilcox time.

Before taking up in detail the evidence of the flora I wish to point out certain general climatic conditions based on cosmic causes and deduced for the Wilcox from studies of recent climates.

It is to be noted that the factors governing atmospheric circulation are general and not local and the relatively slight changes in the relation of land to sea in Wilcox time as compared with the present are entirely too small to have caused much modification of existing conditions. Then as now there was a persistent area of high pressure over the North Atlantic and a low over the continent. Consequently the winds were prevailingly from the east. Cyclonic disturbances like those that originate today in the Gulf of Mexico or those more violent and widespread storms of the West Indian hurricane type which today originate in the Caribbean Sea would traverse at least a part of the Mississippi embayment. So large an area of shallow more or less landlocked water would have a very appreciable effect in raising total temperatures and in the prevention of widely separated extremes. At the same time it would increase the rainfall and increase the width of the marginal lands over which this augmented

rainfall would be effective. Whether or not this would be sufficient to furnish the subtropical conditions that the flora seems to indicate is doubtful. Speculation regarding the Eocene climate of the world as a whole is perhaps out of place, nevertheless it remains true that the sum total of paleontologic evidence indicates that the familiar succession of seasons or of types of vegetation in passing from the luxuriant tropics to the ice-capped poles did not hold good for the Eocene. Paleobotanists have long maintained that the existing climate is essentially a Pleistocene climate of an interglacial character and that for the great bulk of geologic time uniformity and not differentiation has been the rule rather than the exception. While the older paleobotanists were inclined to overestimate the conditions of torridity, it remains true that from the Lower Cretaceous until toward the close of the Oligocene, not to mention still older floras of more remote botanical affinities, whenever fossil floras are found, from beneath the Equator to within the Arctic circle, they show a degree of uniformity that proves that former climates were secularly unlike these of today and as is obvious this floral evidence would be equally convincing if all the vast number of fossil plants were simply called *Phyllites* as in Schlotheim's day and no attempt were made to determine their botanical affinity.

The student of fossil floras is naturally more sanguine and enthusiastic in predicting former physical conditions than perhaps is warranted by his facts. When however a common Upper Cretaceous flora can be traced from Texas to Greenland or when we find in the Eocene such unmistakable forms as *Artocarpus* leaves, *Engelhardtia* fruits, and nuts of the Nipa palm associated with forms as characteristic as ferns of the genus *Acrostichum* all extending almost across the temperate zone in both the eastern and western hemispheres it would seem that the burden of proof that climates were not very different from those of today rests with the physicist and not with the paleobotanist.

It may be noted that all of the Wilcox plants, almost without exception, are plants whose modern representatives inhabit the warmer parts of the earth. There is not a single strictly temperate type in the whole assemblage, the nearest approach to such types being in the genera *Juglans, Myrica, Magnolia, Cercis, Ilex, Nyssa,* and *Frax-*

inus, and in all of these genera or closely related ones there are existing tropical forms. None extend beyond the warmer parts of the temperate zone and some of these as in the case of *Juglans* and *Fraxinus* indicate in their compound leaves their tropical ancestry, as was first pointed out by Grisebach. The ferns are all tropical types and their relative unimportance in the Wilcox flora furthermore indicates that the major part of this flora is a strand flora. This is shown more especially by forms like the Nipa palm which never grows outside of tidal marshes, by *Conocarpus, Laguncularia* and *Avicennia* which inhabit like situations; by coastal marsh or lagoon plants like *Canna, Trapa* and *Sabalites;* and by the large number of strand types that inhabit beaches or the jungle behind the beach ridges or dunes. The more striking of these genera are *Myrica, Artocarpus, Ficus, Coccolobis, Pisonia, Anona, Capparis, Chrysobalanus,* various Lauraceæ, Apocynaceæ, Sapotaceæ and Leguminosæ, *Fagara, Drypetes, Metopium, Ilex, Celastrus, Sapindus, Dodonæa, Reynosia, Rhamnus, Myrcia, Eugenia, Laguncularia, Combretum, Terminalia, Cordia, Citharexylon, Exostema* and *Guettarda.*

It needs but a slight acquaintance with the existing Antillean flora or that of the Florida keys, or in lieu of actual acquaintance a perusal of the as yet too few ecological discussions of the flora of the American tropics or even of Schimper's classic Indo- Malayan strand flora to see at once that the general facies of the Wilcox flora is overwhelmingly that of a strand flora of which some of the elements indicate that they grew on the sandy beaches, others in muddy tidal flats, others between or behind dunes or beach ridges, and others in estuary bayous or marshes. None of the forms can certainly be considered as inland or upland types. Even genera like *Banksia* which is not usually considered a coastal type in the existing flora furnishes *Banksia marginata* Cav. to the coastal sand dunes of South Australia (Tepper) and several others species of the genus occur on the dunes of Queensland, Victoria and western Australia.

Little has been written of the plant associations of the American tropics and collectors notes almost always fail to adequately describe habitats. While the marginal Wilcox lands were low there was such a large area of continent to the northward to draw from, and the long coast furnishes such varied edaphic conditions, that the flora

was far richer than floras of small insular areas of the American tropics of the present, as for example, that of the Bahamas which are relatively close to mainland, where in addition to difficulties of introduction there is relatively great uniformity of edaphic factors and directly adverse factors such as winds, which limit the floral display.

Without pursuing the subject in greater detail it may be assumed to be proven that the Wilcox flora is a typical coastal flora. Compared with recent coastal floras it is at once apparent that its affinities are entirely with those of tropical and subtropical America. It has much in common with the Bahaman flora and that of the Florida keys, but is far richer in arborescent forms. Comparisons with the larger islands of the West Indies show more elements in common, such differences as are apparent being due to the prevalence of porous coral rock along these recent shores while the Wilcox shores were not of this character. The most complete agreement is furnished by the floras along the Caribbean coast from Central America to northern Brazil. A considerable number of genera found in the Wilcox flora do not range through the West Indies at the present time and the explanation seems to be that the Wilcox flora more closely resembles the original flora of the whole American equatorial region which became restricted during the epeirogenetic and climatic changes of the Miocene or Pleistocene and the elements now lacking in the West Indies never regained all of the area of distribution lost at that time.

It may seem improper to say that a flora with abundant forms of *Artocarpus, Nipa, Cinnamomum, Banksia,* etc., is entirely American in character but if the brief sketches in the botanical discussion which follows are read it will be obvious that these genera, oriental in the existing flora, were cosmopolitan in the early Tertiary, so that it would be entirely misleading to draw conclusions from existing distribution alone.

The Wilcox waters of the upper embayment were always shallow; there were fringing bars and lagoons as well as deltas, estuaries and swampy bayous. The deposits in places show river action and streams shifting about over sand flats. Regarding actual temperatures so little is known after all of the relations of modern plants to their climatic environment that results can only be qualitative and not quantitative.

It is obvious that the flora could not have existed if the region was ever visited by frost, and temperatures appear to have been like those found today on the Florida keys. Aside from the meteorological certainty that there was a wide coastal belt of abundant precipitation, there is the confirmation furnished by the flora itself. It would seem to me proper to compare the Wilcox flora with those of the regions to which the somewhat loosely used term subtropical rain forest is applied by plant geographers. Too little is known of the Midway flora for accurate comparisons. Compared with the Upper Cretaceous flora of the embayment area, in which however 40 percent of the genera are extinct, the Wilcox would seem to have become more tropical, a progression from what might be termed a warm temperate to a subtropical rain forest. On the other hand the floras as well as the faunas show a gradual increase of tropical conditions in the later Eocene which culminate in the Oligocene, the flora of which in southeastern North America is strictly tropical.

Lianas were apparently not as common in the Wilcox as they are in the existing floras with which it has been compared. No traces of the Bignoniaceæ, so common in the American tropics, have been detected, the scandent types being represented by *Lygodium, Aristolochia,* Malpighiaceæ, *Canavalia, Pisonia* (?), and *Zizyphus,* I am inclined to think that the great uniformity of climatic conditions together with the abundant rainfall have combined to make the Wilcox flora seem more tropical in character than was actually the case. That reef corals are not found in the Wilcox is, I believe, entirely due to physical conditions other than those of temperature as Vaughan[2] has shown to be the case so often in such a striking manner in recent seas.

I have indicated upon the sketch map (Fig. 1 *C–C*) what I conceive would be the northern limit of range of the Wilcox flora under existing climatic conditions in southeastern North America.

It would seem to be probable that most of the generic types of the Wilcox were differentiated by the close of the Cretaceous. If the equatorial region of America was the place of origin of a majority of those types which have not as yet been recorded from the Cretaceous as I believe to be the case, they must have spread northward along

[2] Vaughan, T. W., *Journ. Wash. Acad. Sci.,* Vol. 4, pp. 26–34, 1914.

the Mississippi Gulf either during the Cretaceous-Eocene interval, during the Midway or during the Midway-Wilcox interval. While the time available for this northward dispersal was thus sufficiently long to account for the migration of even the most slowly spreading forms a short statement on the adaptations and agencies of this dispersal is not without interest. The Wilcox genera with winged fruits or seeds are *Engelhardtia, Paraengelhardtia, Dodonæa, Paliurus, Fraxinus* and the Proteaceæ and Malpighiaceæ. None of these are capable of long flights except those of the last two families and these during high winds might readily be carried for miles along coasts, although it is doubtful if they could have crossed great stretches of open water, even through the agency of a West Indian hurricane. The heavier winged fruits such as those of *Engelhardtia, Paraengelhardtia, Paliurus, Dodonæa* and *Fraxinus* float readily, although as far as I know there is no experimental data to show how long they float in oceanic waters without losing their vitality. Certainly *Dodonæa* has reached the Bermudas in recent times through the agency of the Gulf Stream. Among the Wilcox forms more or less adapted for floating the following genera may be enumerated: *Nipadites, Canna, Taxodium, Pisonia, Sapindus, Sterculiocarpus, Trapa, Avicennia, Solanites, Exostema* and the Combretaceæ. Among the foregoing *Canna, Taxodium, Trapa* and *Exostema* are scarcely adapted for sea voyages while on the other hand, *Nipadites, Sapindus, Sterculiocarpus, Avicennia* and the Combretaceæ are singularly adapted for dispersal by ocean currents and would be in the van of forms colonizing the shores of the transgressing Wilcox sea.

A large number of the Wilcox genera had fleshy or drupaceous fruits and formed the dietary of both mammals and birds. Among these the following may be mentioned: *Myrica, Ficus, Coccolobis, Magnolia, Anona, Asimina, Chrysobalanus, Simaruba,* all the Lauraceæ, Ilicaceæ, Celastraceæ, Myrtaceæ, Ebenaceæ, Sapotaceæ, Meliaceæ, Euphorbiaceæ, Anacardiaceæ, *Zizyphus, Guettarda, Citharexylon, Cordia, Osmanthus, Icacorea, Rhamnus* and *Reynosia.* Many of these have crustaceous stones that pass uninjured through birds or are voided with their vitality unimpaired and these could undoubtedly be carried long distances over seas. Even in the case of soft seeds like those of a large number of the Leguminosæ it has been

found that birds that have eaten greedily often void them uninjured and others meet with fatalities before the seeds are digested and these constitute by no means unimportant factors in distribution. Clement Reid in his discussion of the origin of the British flora gives an instance of a dead wood-pigeon with beans sprouting from its crop, and when it is remembered what a great percentage of birds meet an untimely end it is conceivable that a single hurricane might readily be the means of introducing new forms from the Antilles upon the Wilcox coast. Other Leguminosæ, although more rarely, are dispersed by ocean currents, as is the case in an eminent degree with the modern *Entada* or snuffbox seabean.

All of the storms moved from the equator northward, the main ocean currents had the same general direction, while the prevailing winds were easterly so that all of these important factors combined in causing a relatively rapid introduction and spreading of forms along the Wilcox coasts, so that given favorable climatic conditions and many of the forms need not have taken the time to spread from Central or South America along continuous coasts.

Botanical Character of the Flora.

That the method by which the bulk of the determinations in the present study are made rests upon real and not fanciful affinities is of vital importance, since the resulting climatic and other physical data are largely controlled by these facts. The case is not as intricate or as hopeless as it might seem to the student who remembers the thousand of living and extinct genera. De Candolle estimated the total number of flowering plants to be about 250,000 species. This figure is swollen by the great multiplication of herbaceous species in recent geologic times. The ratio of arborescent to herbaceous types was much greater in the Tertiary than it is at the present time and it seems probable that trees were actually more abundant and varied than in the existing flora. This was certainly true for all Tertiary floras outside the torrid zone and may be readily proved by a consideration of the Eocene floras of North America, the Miocene floras of Europe or to cite an extreme case the Tertiary floras of the Arctic and Antarctic regions.

While the arborescent flora of the temperate zone is relatively

meager, trees increase in passing toward the equator. For example the state of Maryland which is in latitude 38° to 39° 30′ is in effect a cross section of the Coastal Plain, Piedmont Plateau and the Alleghany Mountains with great differences of climate, topography and soils. It is moreover the meeting ground for plants of northern and southern range. In spite of these facts there are only about 150 arborescent forms in its flora. On the other hand in Small's recently published Trees of Florida (1913) there are 366 native and naturalized arborescent forms, and if Florida furnished much altitudinal variation the number would be much larger. For example the arborescent flora of the Philippine Islands includes 665 native species and many additional introduced forms. Even remote oceanic islands if of sufficient size and topographic variety to overcome the adverse action of winds have a large arborescent flora. Thus the Sandwich Islands have 225 native species of trees distributed among 45 families, the larger being the Rutaceæ (32 species), Rubiaceæ (31 species), Campanulaceæ (15 species), Araliaceæ (14 species), Pittosporaceæ (12 species), Palmaceæ (11 species), Myrsinaceæ (11 species), and Malvaceæ (10 species).[3]

The general physical conditions of a remote geological epoch may be more or less completely deduced in advance from the character of the sediments: the run-off from the land can be approximated and consequently the altitude of the land and the probable rainfall as well as any periodicity in these factors. These are all reflected in the sediments. Work like that of Vaughan[4] on the deposits of the Florida Keys or that of Drew[5] on the part played by denitrifying bacteria in the formation of limestones, enables a careful paleobotanist to in a measure predict the character of the flora that clothed the marginal lands. In deposits that teem with the remains of marine life as do many of the Tertiary formations of southeastern North America it is possible to arrive at very close approximations of the actual temperatures of the coastal waters. It may be safely assumed that boreal or temperate floras did not flourish in proximity to trop-

[3] Rock, J. F., "The Indigenous Trees of the Hawaiian Islands," Honolulu, 1913.

[4] Vaughan, T. W., Carnegie Institution, Publication 133, 1910.

[5] Drew, G. H., Yearbook, Carnegie Institution, No. 10, 1911.

ical marine faunas: that plants reflected their environment in the past as in the present.

A considerable number of botanists love to dwell upon the temerity of their paleobotanical friends in venturing to determine leaf impressions. I admit at the outset that some determinations are much too sanguine, especially when based upon fragmentary materials. There is more or less convergence in foliar characters in unrelated or remotely related families and there is also considerable variation in the leaves of a single species, but the fact remains that foliar characters in general are more conservative than those derived from almost any other organs of plants. They are subjected to less complex environmental factors and always have been. It should be remembered that characters less essential in the vital activities of plants, such as leaf form, when once acquired, may continue practically unchanged for thousands of years and afford a surer clue to relationship than characters more immediately within the field of action of natural selection. This is shown by the persistence of fern fronds on the Paleozoic Pteridosperms; by the uniformity of Cycad-like fronds from the Permian to the Cretaceous; and by the striking persistence of dicotyledonous foliar types from the Mid-Cretaceous to the present. It is paralleled by Dall's observations on the persistence of superficial and ornamental shell characters in the Mollusca from the Cretaceous to the Recent.

The opinion I mention in a preceding paragraph is mainly the result of ignorance both of foliar characteristics and paleobotanical literature, and an unwillingness to spend the time necessary for a mastery of the subject. I have tested systematic botanists time and again with recent leaves and the results are not especially creditable. They generally know that leaves are green in color and that some are simple and others compound: they may even know whether the margins are entire or toothed, but the venation is usually a closed book. I know of but one manual that pretends to pay careful attention to foliar characters and that is Sargent's "Tree Book" and even here the figures pay no attention to venation.[6] In the tropics where flowers and fruits are often unobtainable or beyond reach it is easy to

[6] Sudworth's "Trees of the Pacific Slope" is the most admirable work in this respect that has ever been published.

learn to recognize most arborescent forms by their habit and foliage but to most botanists, systematic or otherwise, anything beyond the floral structure receives but scant attention.

It is reasonable to conclude that palms and tree-ferns were never boreal plants that have in the course of ages become restricted to the tropics as Naumayr once suggested in an effort to explain their presence within the Arctic circle on other than climatic grounds. Uniformity of conditions is the foundation upon which the whole fabric of our knowledge of past events rests and it is just as unscientific to assume that the carrying power of water was not conditioned by its velocity during the Tertiary as it is to assume that insolation, humidity, rainfall, winds and all the other factors that constituted the environment of the vegetation, had effects different in kind from their effects on the living flora.

In a study of this sort the chief emphasis should be based upon comparisons with the existing relatives of the fossil forms and not upon a search among the illustrations of works devoted to the study of previously described forms, often from remote regions, for what appears similar. The latter should not be neglected however and no descriptions are complete unless they include a discussion of the resemblances and differences of previously described forms that show similarities to the form in hand with their geologic and geographic destribution. Even the most trivial characters of the fossil should be carefully noted since all are or will become valuable in future studies. The living representatives, their habitat, range and variation are of the greatest importance in determining paleoecology.

Unless there is clear evidence of transportation it may be assumed that strand plants and upland plants will not be found in association and if such seems to be the case, additional study may reveal the errors of determination.

That all floras are dynamic and not static: that all their elements are more or less plastic in their reactions to the infinite complexity of their environment raises a certain amount of scepticism regarding the methods and results of what may be called paleoecology. This is especially true since so little is known regarding the precise relations between existing plants and their environment. At the same time there is no other method available and it must be considered to be a

legitimate method until negatived in human experience. If it be assumed untrue there is no limit to idle speculations as futile as those of medieval times.

The Wilcox flora as described in the present study comprises considerably more than 300 species—the exact number is without significance since it is so largely dependant on accidents of preservation and discovery, and since it is also considerably influenced by the evaluation of specific characters. The number might readily be increased to 400 if fragments of new forms were considered the basis for the description of species.

This flora is therefore one of the largest floras as yet known from a single geologic horizon in a single area, although it is considerably overshadowed numerically by the so-called Fort Union flora of the Rocky Mountain Province, which however covers a greater geographic area and a longer interval of time.

Compared with foreign Eocene floras of similar age it may be noted that Ettingshausen enumerated 72 genera and 200 species from the London Clay of the Island of Sheppey[7] and 116 genera and 274 species from Alum Bay on the Isle of Wight.[8] I mention these two English floras specifically since while never adequately described they are at least partly contemporaneous with that of the Wilcox, as I hope to show in the chapter on correlation, and they therefore offer various interesting details for comparison as will appear on subsequent pages.

The Wilcox flora comprises 128 genera in 59 families and 33 orders. The Thallophyta are represented by a few species of leaf-spot fungi, and if the student were to follow the fashion set by the older continental paleobotanists the so-called species of spot-fungi could be increased many fold, as I have only picked out for enumeration certain conspicuous or characteristic types. The Bryophyta, as is usually the case in fossil floras, are entirely unrepresented, although the sediments are often of a character to have preserved them in perfection if they had been present, and the assumption is logical that they were either confined to more northern latitudes at this time or were an exceedingly minor element in the flora. The Pterido-

[7] Ettingshausen, *Proc. Roy. Soc. Lond.*, Vol. 29, 1879, pp. 388–396.

[8] Ettingshausen, *Ibidem*, Vol. 30, 1880, pp. 228–236.

phyta which are such a preponderating element in all fossil floras up to the Middle Cretaceous are represented by a doubtfully determined Lycopod and six species of ferns.

Ferns are among the most abundant (in specific differentiation) vascular plants in the flora of tropical America, the island of Jamaica being especially celebrated for its fern flora. Grisebach enumerated 340 species of ferns in his "Flora of the British West Indies" published in 1864. In Urban's more recent work 182 species of the Polypodiaceæ alone are recorded from Porto Rico. The following five genera have been recognized in the Wilcox: *Aneimia, Lygodium, Asplenium, Pteris* and *Meniphylloides*—each represented by a single species except the genus *Asplenium* which has two species. While six species seems a small number of ferns in a subtropical flora like that of the Wilcox it is just twice as many as have been found in the contemporaneous deposits of Alum Bay on the Isle of Wight where the remains of an extensive flora is preserved in the pipe-clays. The explanation of this seeming disparity between the fern representation in the Lower Eocene and in modern floras is readily formulated and it will also indicate the reasons for thinking that the real Wilcox fern flora if it were available for study would be a rich and varied one, comparable at least with the existing fern flora of the lowlands of subtropical America.

The known Wilcox flora is almost entirely a coastal flora made up very largely of strand types. Very few elements in it can be legitimately considered as derived from inland areas by stream transportation, in fact their condition of preservation alone proves that they grew in the immediate vicinity of where they are now found as fossils. With a few striking exceptions the existing tropical and subtropical fern floras are floras of humid inland or upland habitats, for example the majority of the Jamaican ferns are found on the Blue Mountains. The most striking exception to this statement is the genus *Acrostichum* which strangely enough has not yet been positively recognized in the Wilcox flora although it was widespread along the shores of the Mississippi Gulf in the succeeding Middle Eocene (Claiborne) and Lower Oligocene (Vicksburg) floras, as abundant apparently as it is in the existing flora of tropical tidal marshes in both the Eastern and the Western Hemispheres. Another

fern type liable to be present in coastal thickets is the genus *Lygodium* with its scandent habit, and this genus is represented in the Wilcox flora by both sterile and fertile fronds. It is likewise common in the Claiborne and Vicksburg floras and in Tertiary floras generally. Besides *Lygodium,* the family Schizaeaceæ is represented by a species of *Aneimia* which must also be considered to have been a coastal type in the early Eocene as are some of its species at the present time, since very similar species of *Aneimia* are found at a very large number of Eocene coastal deposits both in this country and abroad.

The remaining four species of Wilcox ferns are all referable to the family Polypodiaceæ which is the dominant existing family of the fern phylum. The two species of *Asplenium* are types readily matched by existing Central American species. The *Pteris,* not certainly identified as a true species of this common cosmopolitan type, had stout coriaceous fronds and may have been transported since it occurs at only two localities in the Wilcox and at one of them it is in a fragmentary condition. This supposition receives some support from its presence in the basal Eocene of the Rocky Mountain province after the sea had withdrawn from that area and after there had been a large amount of volcanic activity and more or less uplift. The genus *Meniphylloides* is a unique type as yet peculiar to the Wilcox flora although it is closely related to the similarly unique genus *Meniphyllum* Ettingshausen and Gardner from the Middle Eocene (Lutetian) of England and both are closely related to and possibly the progenitors of the existing genus *Meniscium* which has at least one species that is close to the Wilcox form. *Meniphylloides* is only found at two localities near the top of the Wilcox and its probable habitat is not known. The remains are broken but are associated with a typical strand flora.

It will be seen that of the Wilcox ferns whose habitats can be surmised all are coastal types and when we recall that the mainland was relatively low throughout Wilcox time it is not surprising that the ferns are not more strongly represented. By a specialization of habitat in modern equatorial regions a considerable proportion of the flora becomes epiphytic, the smaller ferns being commonly so. None of the members of the extensive Wilcox flora can be regarded

as epiphytes with the possible exception of *Lycopodites? eolignitica* which is such a rare and poorly represented form that it is without significance. Apparently epiphytes were not conspicuous in the Wilcox coastal floras so that this possible source of supply for additional fern species is also eliminated.

The Gymnospermæ so conspicuous in Mesozoic floras are relatively unimportant in the Wilcox flora, a feature due to their general unimportance in Cenozoic floras and to their intolerance of the habitats and climatic conditions indicated by the *tout ensemble* of the Wilcox flora. All of the five Wilcox gymnosperms are referred to the relatively modern family Pinaceæ and none of the genera are especially close to Mesozoic types. The Cycadaceæ which might be expected to be represented by *Zamia*-like forms have not been found although the presence of typical *Williamsonia* fructifications in the Upper Cretaceous of the coastal plain indicates that the Cycad phylum had not been long extinct in this area.

The Angiospermæ, beyond all odds the dominant type in existing floras, was as clearly dominant in Wilcox time since to it belong over 94 per cent. of the known Wilcox flora. Of these numerous angiosperms only seven are referable to the Monocotyledonæ. It is true the number of monocotyledons might have been increased by describing the various sedge or grass-like fragments that are not uncommon at certain localities. None of these have, however, been dignified by names except a single form each of *Poacites* and *Cyperites* which were only retained since they were already in the literature. That only three species of palms have been recognized is remarkable since palms were well differentiated at this time and various genera such as *Phœnicites, Thrinax, Geonoma, Bactrites, Manicaria,* etc., are recognized in our later Tertiaries. In the contemporaneous deposits of Sheppey of the 30 monocotyledons enumerated by Ettingshausen (op. cit., p. 393) 22 species are palms. On the other hand the Alum Bay flora contemporaneous and not far distant from the Sheppey deposits furnished only 6 monocotyledons. This contrast indicates that the fruits accumulated at Sheppey in the delta of an Eocene river system contain interior forms not present in the coastal region represented by the Alum Bay clays and that inland from the Wilcox coast the display of monocotyledons suitable to the Wilcox environmental conditions flourished but failed of preservation.

Since the early Eocene floras of Europe are so much like those of southeastern North America an enumeration of the Sheppey palms is of considerable interest. They include the genera *Nipa, Œnocarpus, Areca, Iriartea, Livistonia, Sabal, Chamærops, Thrinax, Bactris, Asterocaryum,* and *Elæis.* Of these *Nipa* and *Sabal* are represented in the Wilcox flora while *Thrinax* and *Bactrites* are present in the embayment area in the Middle Eocene (Claiborne). The Order Palmales, or more properly Arecales, has a single existing family the Arecareæ (Palmæ) with about 150 genera and considerably over a thousand existing species about equally divided between the oriental and occidental tropics. There are no temperate outliers, although some species extend for considerable distances into the temperate zone as for example *Sabal adansonii* which ranges northward along the Atlantic Coast as far as North Carolina. The present distribution of the palms is a good illustration of modern continental floral diversities succeeding a Tertiary cosmopolitanism of floras and it shows further the part played by isolation in evolution, also indicated by the abundance of monotypic genera in the Orient where the tropical area is so much broken. Not a single species or genus is common to the two hemispheres and even the tribes are almost all either oriental or occidental.

Regarding the origin of the palms most students regard the Pandanaceæ (screw pines) as their probable ancestral stock and while the latter family is entirely oriental at the present time this was not true in the Tertiary, and it is perhaps significant that the existing genus *Phytelephas* which is regarded as intermediate between the Pandanaceæ and the Arecaceæ is exclusively American, and that genera now exclusively oriental like *Nipa* and *Phœnix* are represented in the American Tertiary (*Nipa* in the Wilcox and *Phœnix* in the Vicksburg). There is no warrant for asserting that palms are of occidental origin, at the same time their oriental origin is equally difficult of proof and what we know of their geologic history conclusively shows the inadequacy of the existing distribution in a discussion of their phylogeny.

The three Wilcox species of palms comprise a fan palm and two feather palms. The *Chamædorea* leaves represent a small palm whose numerous modern allies are confined to America, being richest

in species in the humid mountainous regions of Central America. It is not a coastal form and is not found in association with the typical Wilcox strand flora, occurring only in the basal Wilcox of Choctaw County, Mississippi, and at the base of the transgressing Upper Wilcox deposits in Saline County, Arkansas. Its rarity and occurrence in basal beds would seem to indicate that its area of growth was inland and only reached in these two cases by the landward migration of the strand line. The *Sabalites,* which I have compared with the existing *Sabal palmetto,* is common everywhere from the base to the top of the Wilcox. It is distinctly a coastal type, rather of the lagoons, bayous and estuaries than of the strand. This is indicated by the fragmentary nature of the remains at very many localities and the occurrence of innumerable complete specimens at other localities as for example at Oxford, Mississippi, where the presence of unios and the local unconformities indicate estuary conditions.

The Nipa palm found in the Upper Wilcox is clearly an inhabitant of muddy tidal shores so that it would naturally be expected in the laminated clays of the Upper Wilcox. Its single modern representative is tolerant of water of considerable salinity and is a member of the mangrove association of the Orient. It shows many points of affinity with the Pandanaceæ and has never before been found in the Western Hemisphere. Like so many forms which are strictly oriental in the existing flora such as *Cinnamomum, Artocarpus, Phœnix,* etc., it enjoyed a cosmopolitan range during at least the earlier half of the Tertiary period.

A somewhat full account of *Nipa* has been recently published by me[9] and need not be repeated in the present connection.

The single species of *Canna* of the Wilcox represents a strictly hygrophilous type which is confined to America in the existing flora. It is an inhabitant of estuary and river swamps near the coast, and that the Wilcox species inhabited a similar situation is indicated by its restricted occurrence and its association with *Sabalites* near the mouth of a Wilcox river, which on other grounds is known to have been present in Lafayette County, Mississippi.

The Dicotyledonæ of the Wilcox as might be expected are largely choripetalous forms since there are over 250 species of Choripetalæ

[9] Berry, E. W., *Am. Jour. Sci.* (IV.), Vol. 37, pp. 57–60, Fig. 1, 1914.

(Archichlamydeæ) and only 35 species of Gamopetalæ (Sympetalæ). At the same time the representation of Gamopetalæ is really much larger than might be expected thus early in the Eocene and many families often thought to be relatively more modern have been found to be represented.

The following orders of Choripetalæ are not represented in the Wilcox flora: Casuarinales, Piperales, Salicales, Balanopsidales, Leitneriales, Santalales, Sarraceniales and Opuntiales. The absence of the Balanopsidales, Sarraceniales and Opuntiales is not remarkable since they are all specialized types and the rather uniform habitats of the cacti and their relatively modern evolution both conspire to eliminate them from Eocene coastal floras. The presence of the primitive Casuarinales and Piperales might be expected especially since there is a well marked Piper-like form in the Upper Cretaceous of Alabama. The Salicales while prevailingly temperate forms are abundantly represented in the Upper Cretaceous floras of the embayment area and the Santalales have also been recorded from the American Upper Cretaceous and are present in the European Tertiary.

Those alliances of Gamopetalæ which are not present in the Wilcox to be enumerated presently are mainly the great modern and temperate zone groups. For example there are no Wilcox species of Ericales, Labiatæ, Convolvulaceæ, Bignoniaceæ. Scrophulariaceæ, Plantaginales, Valerianales or Campanulales, this proving not only the essential modernness of the evolution of the Compositæ[10] but firmly establishing the thesis that the Wilcox flora is a subtropical and not a temperate flora.

The following are the larger families in the Wilcox flora: The Lauraceæ with 30 species, Cæsalpiniaceæ with 26, Moraceæ with 23, Papilionaceæ with 22, Rhamnaceæ with 14, Sapindaceæ with 13, Sapotaceæ with 12, Myrtaceæ and Mimosaceæ each with 11, Combretaceæ and Anacardiaceæ each with 9, Juglandaceæ with 8, Celastraceæ with 7, and the Proteaceæ and Apocynaceæ each with 6.

The largest single genus is *Ficus* with 18 species, then comes *Cassia* with 12, *Sapindus* with 9, *Gleditsiophyllum* with 8, *Oreo-*

[10] The fruit described as *Carpolithus hyoseritiformis* is probably referable to the Compositæ.

daphne, Sophora and *Anacardites* each with 7, *Cinnamomum, Nectandra, Rhamnus, Myrcia* and *Bumelia* each with 6, and *Celastrus, Dillenites,* and *Apocynophyllum* each with 5. Ten species are referred to the form-genus *Carpolithus* and this number could readily be greatly increased if all the unidentified seeds were named and described.

The amentiferous families, in accordance with their Upper Cretaceous deployment and their undoubted primitive and not reduced character, are represented in the Wilcox flora by fourteen species, a number of which are individually abundant.

The Juglandales[11] are represented in the Wilcox by three species of *Juglans* only one of which, *Juglans Schimperi,* is at all common; by a doubtfully determined species of *Hicoria;* by three well-marked species of *Engelhardtia* and by an extinct type, *Paraengelhardtia,* of a habit similar to that of *Engelhardtia.*

The genus *Juglans* is one of the earliest of the still existing dicotyledonous genera to appear in the fossil record and it is continuously represented in fossil floras from the Mid-Cretaceous to the present. There are about 25 Eocene species of Walnut and they range during that period from the Gulf region to Alaska and Greenland, and are also present in the tropical forests of the Egyptian Fayum in the early Oligocene. The outlying existing species in the West Indies and under the equator in South America prove that in spite of the northward range of the Asiatic species in Manchuria and of some of the North American species into New England and southern Ontario, its progenitors were at least subtropical types, a fact corroborated by their foliar character since it is a well-known fact that compound leaves indicate tropical ancestry, and this is abundantly proven in the case of *Juglans* by its associates in the fossil floras where it has been found represented.

The genus *Engelhardtia*[12] is one of the most interesting Wilcox genera. In the first place the identification of its leaves is corroborated by two varieties of characteristic winged fruits.

The genus was described by Leschen in 1825 and contains about

[11] See Berry, E. W., "Notes on the Geological History of the Walnuts and Hickories," *Plant Woirld,* Vol. 15, 1912, pp. 225–240.

[12] See Berry, E. W., *Am. Jour. Sci.* (IV.), Vol. 31, 1911, pp. 491–496; *Plant World,* Vol. 15, 1912, pp. 234–238, Figs. 3, 4.

ten species of the southeastern Asiatic area. These range from the northwestern Himalayan region, where they extend a short distance north of the Tropic of Cancer, through farther India and Burma to Java and the Philippines. The pistillate flowers are small and are grouped in paniculate spikes. They develop into small drupe-like fruits, each of which is connate at the base to a large expanded trialate involucre.

A single little known species, rarely represented in even the larger herbaria, occurs in Central America and is the type and only species of the genus *Oreomunnea* of Oersted. This is much more restricted in its range than are its kin beyond the Pacific. *Oreomunnea* is very close to *Engelhardtia,* and for the purposes of the paleobotanist the two may be considered as identical since they represent the but slightly modified descendants of a common ancestry which was of cosmopolitan distribution during the early Tertiary. The present isolation of *Oreomunnea* furnishes a striking illustration of the enormous changes which have taken place in the flora of the world in the relatively short time, geologically speaking, that has elapsed since the dawn of the Tertiary.

The principle has frequently been enunciated that when closely related forms are found in the existing flora of the world, restricted in range and isolated from their nearest relatives, or when other existing genera are monotypic, it is quite safe to predict an interesting and extended geological history. *Engelhardtia* proves to be another illustration of this principle, for its peculiar three-winged fruits have been known in the fossil state for almost a century. They were long unrecognized, however, and the earlier students who described them compared them with the somewhat similar winged fruits of the genus *Carpinus* (Betulaceæ). With the botanical exploration of distant lands in the early part of the nineteenth century, specimens of *Engelhardtia* began to be represented in the larger European herbaria, and Baron Ettingshausen, that most sagacious of paleobotanists, as long ago as 1851 pointed out that certain supposed species of *Carpinus* were really fruits of *Engelhardtia.* He returned to the subject in 1858 without, however, actually changing the names of any of the supposed species of *Carpinus* nor does he seem to have been aware of the existence of a living species of *Engelhardtia* (*Oreomunnea*) in Central America.

Since Ettingshausen's announcement a dozen or more fossil species have been described. The oldest known European form occurs in the lower Oligocene (Sannoisian) of France and the species become increasingly abundant throughout southern Europe, especially toward the close of the Oligocene and the dawn of the Miocene, Saporta stating that the slabs from the leaf-beds at Armissan in southeastern France are thickly strewn with their peculiar fruits. Fossil forms continue in Europe throughout the Miocene and Pliocene and specimens of late Miocene or early Pliocene age are recorded from Spain, France, Italy, Croatia, and Hungary.

The Wilcox species are somewhat older than any of the known European forms

The existing *Engelhardtias* are upland forms and this may possibly have been their habitat in Wilcox times although their abundance at different localities along the Wilcox coast would seem to indicate that this was not the case.

The genus *Paraengelhardtia,* which is a unique type confined to a single locality in the Wilcox, is clearly allied to *Engelhardtia,* as I have shown in the systematic chapter. It seems probable that it represents a survival of the ancestral stock from which *Engelhardtia* was derived since its fruits are more primitive and indicate ancestral forms with smaller bracts comparable with the bracts of *Juglans* or *Hicoria* which in the course of time became accrescent and subsequently deeply trilobate. The primitive character of *Paraengelhardtia* and the presence of true *Engelhardtias* in the Wilcox so much earlier than their first occurrence in Europe suggests that America was the original home of the *Engelhardtia* stock, although this supposition cannot be verified or disproved until a Tertiary paleobotanical record for the continent of Asia is available.

The Myricales contains but two species of *Myrica* in the Wilcox flora. *Myrica* is a very old generic type with a large number of fossil species ranging from the Middle Cretaceous to the present. The existing species are relatively few in number and widely scattered geographically and represent survivors from a Tertiary cosmopolitan distribution. *Myrica*[18] is much less abundant in the Wilcox

[18] The allied and monotypic genus *Comptonia* which by some students is included in *Myrica* has an extended geologic history which has been discussed by Berry, *Amer. Nat.*, Vol. 40, 1906, pp. 485–520, pl. 1–4.

than in the European Tertiary, although it was present in the embayment area in the late Upper Cretaceous (Ripley formation of Tennessee). Its meager representation in the Wilcox time may be due to the more tropical climate conditions. The modern Myricas are temperate and subtropical and a number of the species are coastal forms of either swamps or sand dunes. *Myrica elæanoides* was evidently a coastal form and so was *Myrica wilcoxensis*. The latter is very similar to the existing *Myrica cerifera* which ranges from New Jersey to Texas and is also found on the Bermudas and Bahamas. It is most abundant and vigorous in the sandy swamps along the south Atlantic and Gulf coasts and its habitat may be compared with that of *Myrica wilcoxensis*. The latter seems to be the ancestral stock of a very similar species which occurs along the Middle Eocene (Claiborne) coast of the embayment.

The order Fagales, which includes such important timber trees of the temperate zone, is comprised by the two families Betulaceæ and Fagaceæ, together containing about 450 existing species, of which three fourths belong to the Fagaceæ. Only the latter family is represented in the Wilcox although the Betulaceæ are characteristically developed in the Upper Cretaceous of North America.

The family is unrepresented in the Wilcox flora probably because the climate was too warm and this reason may also account for the absence of true oaks since the Fagaceæ are represented in the Wilcox flora by only the genus *Dryophyllum* with four rather widespread and often common species.

The genus *Dryophyllum* is of worldwide distribution and consistently uniform characters in the various horizons of the late Cretaceous and early Eocene from the Senonian to the Ypresian stages. It especially characterizes the dawn of the Eocene and represents the ancestral stock from which the genera *Castanea, Castanopsis, Pasania* and *Quercus* took their origin, although this origin was in the late Cretaceous. As might be expected *Dryophyllum* has long since become extinct. The Wilcox species were apparently strand types as were also the numerous species enumerated by Debey, the describer of the genus, from the sandy shores of the Upper Cretaceous sea of Rhenish Prussia. *Dryophyllum* is abundant in the Montian of Belgium and in the littoral sands of Ostricourt and Belleu in

France. In the systematic chapter detailed comparisons are made between the Wilcox and the foreign species, which show a striking parallelism.

The Urticales includes the families Ulmaceæ, Moraceæ and Urticaceæ together containing about 1,600 existing species. The Urticaceæ are largely herbaceous forms and the Ulmaceæ are mostly extratropical.

The Ulmaceæ comprise thirteen genera and about 140 existing species, widely distributed in temperate and tropical regions. A single species of *Planera* described originally by Newberry from the Western Eocene is doubtfully identified from the Wilcox. The genus is monotypic in the existing flora and confined to wet swampy situations in the warm temperate region of southeastern North America. Its geologic history goes back to the Upper Cretaceous at which time species have been recognized along the Atlantic coast from North Carolina northward. Thus there is no reason why it should not have been present in the early Tertiary of the embayment unless it be argued that the climate was too warm.

The Moraceæ, by far the largest family of the order Urticales and the only one certainly represented in the Wilcox flora, contains between 900 and 1,000 existing species segregated among about 55 genera, of which the genus *Ficus* is by far the largest, including about 60 per cent. of the existing species of the family. The Moraceæ are distinctly tropical and warm temperate types and are most abundant in the oriental tropics, although the dominant genus *Ficus* is widespread and the family is also largely represented in the South American tropics.

There are at least 18 monotypic genera of which one is North American, four South American, four African, and nine Australian. No single tribe is confined to a single continental area and all show apparent anomalies of distribution due to our lack of knowledge of their geologic history. The genera *Ficus, Artocarpus* and *Artocarpidium* go back to the base of the Upper Cretaceous and numerous additional genera appear in the Eocene.

There are 23 species of Moraceæ in the Wilcox flora. The genus *Artocarpus* is represented by three well-marked species. In the existing flora the two score known species of *Artocarpus* are confined

to the southeastern Asiatic region[14] although some of them are cultivated in all tropical countries. The tribe *Euartocarpeæ* of which *Artocarpus* is the largest existing genus, have, however, five of their genera confined to Central and South America, one confined to tropical West Africa, two confined to the southeastern Asiatic region, one to Borneo and one ranging from Japan to Australia. While the geologic history of *Artocarpus* is only imperfectly known at least 15 different fossil species have been described. The oldest is a well-marked form based on characteristic leaves and parts of the fruit which show the typical surface features. It has been fully described by Nathorst[15] and comes from the Atane beds (Cenomanian) of West Greenland. Slightly younger is a less well-defined form recorded from the Emscherian of Westphalia, and the somewhat doubtful genus *Artocarpophyllum* of Dawson from the Upper Cretaceous of Vancouver Island. Another species is recorded from the Laramie formation and the genus is widely distributed in the basal Eocene of North America. It continues in the Mississippi Gulf region until the close of the Oligocene, the last recorded occurrence being in the Alum Bluff sands at Alum Bluff on the Apalachicola River. On the Pacific coast it is found in deposits in California and Oregon which are referred to the Miocene. In the European area it occurs in the Tongrian of France, the Tortonian of Baden, the Pontian of France and Italy and the Pliocene of Italy. It is present in both the Pliocene and Pleistocene of the island of Java.

Artocarpus is said to be represented by petrified wood in the Oligocene of the island of Antigua and it was evidently a member of the American flora from the Upper Cretaceous until late in the Tertiary, although like the genera *Cinnamomum, Nipa, Phœnix,* etc., it is not represented in post-Pleistocene American floras. An extinct genus related to *Artocarpus* and named *Artocarpoides* by Saporta, who described several species from the Paleocene of France, is represented by a single Wilcox species.

[14] It is found throughout Oceanica and was present in the Hawaiian and Marquesas when they were first visited by Europeans. It was introduced into the West Indies in 1793.

[15] Nathorst, *Kgl. Svenska Vetens-Akad. Handl.*, Bd. 24, No. 1, 1890, 10 pp., 1 pl.

The genus *Cecropia* with about 40 existing species confined to the tropics of South America has two species in the Aquitanian of Bohemia and the Midway and Wilcox form described as *Ficus* sp. is very probably a representative of this genus.

The genus *Pseudolmedia,* with five existing species in the American tropics, has a well marked species in the Wilcox flora. As far as I know it has not heretofore been recorded in the fossil state although it is probable that some of the very numerous fossil species of *Ficus* may represent *Pseudolmedia.*

The genus *Ficus* is represented by numerous species in the Wilcox flora no less than eighteen having been described and a number of these are individually abundant. They include the narrow lanceeolate forms of the *Ficus elastica* type, with close-set laterals, as well as open-veined lanceolate forms, and the shorter and broader palmately veined forms. None are lobate or have toothed margins. *Ficus* was evidently much more abundant and varied along the Wilcox coast than it is today throughout the West Indies and more nearly comparable in this respect with the display of figs in the East Indies or in tropical South America.

The number of fossil forms that have been referred to *Ficus* are very numerous, numbering perhaps 300 species. None are certainly known from the Lower Cretaceous, the genus *Ficophyllum*[16] being entirely doubtful. In the Upper Cretaceous, however, *Ficus* is very widespread and abundant, seemingly indicating a Lower Cretaceous ancestry as yet unknown. The Cenomanian stage has furnished 3 species in Greenland, 6 along the Atlantic Coast and 24 in the interior of North America, as well as 11 in Saxony, Bohemia and Moravia. The succeeding Turonian stage furnishes 4 species in Bohemia and the Tyrol, and several in North America (Tuscaloosa, Magothy, Black Creek, Eutaw formations). Later Upper Cretaceous horizons have abundant species of *Ficus* everywhere throughout North America and Europe as well as in Greenland, Australia and New Zealand, and this cosmopolitanism continues throughout the Tertiary, there being about 50 Eocene species, about 60 Oligocene species, 90 Miocene species and 20 Pliocene species. Africa is added to the record in the basal Oligocene, and Asia in the Miocene.

[16] See Berry, E. W., Md. Geol. Surv., Lower Cret., 1911, pp. 502–506.

The fossil records will have to be much more complete before the original center of radiation of the Moraceæ can be determined, the present brief sketch can be said to merely indicate that not only *Ficus*, but other genera like *Artocarpus* that are entirely oriental in the present, were normal elements in North America floras, from the time of the modernization of these floras at the beginning of the Upper Cretaceous onward. Along our east coast, they apparently became restricted in their range at the dawn of the Miocene and they apparently never after became as important in southeastern North America as they had been, or as they are in the recent flora of the Orient.

The order Proteales includes the single family Proteaceæ with about one thousand existing species. They include the prominent arborescent forms of Choripetalæ in the Southern Hemisphere, to which region all but the four genera *Roupala, Protea, Leucospermum* and *Helicia* are confined. They are usually considered as Australian types, in fact the majority of the genera and species are confined to that continent, nevertheless there are four genera in South America together containing over fifty existing species, and there are several genera peculiar to the African flora; and the genus *Helicia* is predominantly Asiatic.

The geologic history of the Proteaceæ is perhaps one of the most striking instances that paleobotany affords of the great difference in geographical distribution in former ages from what could possibly be inferred from a study of the present geographical distribution of the members of this family, although there are some significant features in the distribution of the recent forms that will be alluded to in a subsequent paragraph.

The discovery of fossil forms of Proteaceæ in the Tertiary deposits of Europe was the inspiration of a considerable literature[17] and was the occasion of a rather acrimonious controversy regarding their botanical affinity. This is well illustrated in the dissenting opinions expressed by the botanists Hooker and Bentham who both regarded fossil leaves as undeterminable. Starting with this apriori principle it is difficult to see how they could arrive at any other conclusion.

[17] See the writings of Unger, Heer, Ettingshausen, Schimper, Schenk and Saporta.

The most expeditious refutation of their opinion is furnished by the present distribution of some of the genera, *e. g.*, the genus *Roupala* has 36 species in tropical America, 2 in New Caledonia and 1 in Queensland: the genus *Embothrium* has four Andean species and one in Australia: the genus *Lomatia* has 3 species in Chile, 4 in Australia and 2 in Tasmania. It follows unless one is prepared to subscribe to the doctrine of special creation for each continent or to the independent evolution on separate continents of different species of the same genus, that during their geologic history these genera must have ranged over intervening areas, so that if the Cretaceous and Tertiary plants of the northern hemisphere with fruits and leaves of the Proteaceæ are not related to the genera that they resemble most, then forms with leaves and fruit resembling those of other families must be fossil Proteaceæ, which ought to seem absurd, even to an English botanist. As a matter of fact, while exception may justly be taken to some determinations of Unger, Ettingshausen and Heer, they in no wise affect the main body of facts and there is so much collateral evidence furnished for example by the geologic history of the Araucarian conifers, and the history of the Proteaceæ is so similar to that of the Myrtaceæ and Leguminosæ—the two other great families of the existing Australian flora, that the evidence seems conclusive.

Turning now to the fossil record those who follow the opinion of Hooker or Bentham will see how vast and substantial are the supposed illusions of the paleobotanists. In addition to the two extinct genera in the Wilcox flora I have fossil records of 32 genera of Proteaceæ, although this is artificially enlarged by the joint usage, according to taste, of names like *Dryandra* and *Dryandroides, Banksia and Banksites,* etc. A brief consideration of these genera with fossil representatives will prove valuable.[18]

The genus *Protea* Linné, from which the family takes its name, has about 60 existing species occupying disconnected areas in Central and South Africa. To it have been referred a middle Cretaceous species from Saxony; 3 Aquitanian species from Prussia, Bohemia and Greece; 1 species from the Burdigalian of Italy; 1 from

[18] This list is not complete but sufficiently so for the purpose of this discussion.

the Helvetian of Switzerland and one from the Messinian of Italy. Allied to *Protea* but possibly more generalized is the genus *Proteoides* of Heer. This has several Tertiary species and a considerable number of Upper Cretaceous species (15). There are two each in the Cenomanian of Bohemia and Lesina, two in the Atane beds of Greenland, three in the Dakota sandstone of North America, one in the Tuscaloosa formation of Alabama, one in the Middendorf beds of South Carolina, one in the Cretaceous of Australia, two in the Vancouver Island Cretaceous and one in the Senonian of Saxony.

The genus *Proteophyllum* Velenovsky[19] a still more generalized proteaceous type has seven species (Saporta,. 1894) in the Albian (Vraconian) of Portugal and 8 species in the Perucer beds (Cenomanian) of Bohemia. Another generalized type is *Proteopsis* Velenovsky with a single species in the Cenomanian of Bohemia. The genus *Proteæphyllum* of Fontaine containing 2 species in the Patuxent fomation (Neocomian) of Virginia I regard as entirely worthless.[20] The genus *Conarrhenes* Labill with one existing species in Tasmania has a single species based on both foliage and fruit in the Miocene of Carniola according to a determination of Ettingshausen's which may well be viewed with suspicion. The genus *Conospermum* Smith with about 33 existing species in Australia has two fossil species in the Oligocene of Styria and one in the Miocene of Carniola, while the somewhat less definite genus *Conospermites* (Ettingshausen, 1867) has a fossil species in the Upper Cretaceous of Australia and one in the Cenomanian of Saxony and Bohemia.[21]

The genus *Helicia* Lour. is of especial interest since it is found farther north in the existing flora than any other member of the family. There are about 25 modern forms, mostly Indomalayan, but a few still survive in or have recently spread to Australia. The fossil record includes a species in the Oligocene of Styria and another in the Pliocene of Italy. The genus *Lambertia* Smith with 8 existing Australian species has a single fossil species in the Miocene of Carniola. The genus *Hakea* Schrad. with 100 recent Australian

[19] Velenovsky, Kvetena českého cenomanu, 1889, p. 18.

[20] See Berry, Md. Geol. Surv., Lower Cretaceous, 1911, pp. 494–499.

[21] I regard Fontaine's determination of a species in the Lower Cretaceous of Virginia as worthless.

species has eleven fossil species in the Oligocene of Europe; in France, the Tyrol, Saxony and Greece; and no less than 17 Miocene species in France, Italy, Switzerland, Baden, Hesse, Prussia, Bohemia, Austria, Styria, Croatia and Hungary.

The genus *Knightia* R. Brown with a modern species in Australia and 2 in New Caledonia has a fossil form in the Eocene of Australia and another in Graham Land[22] in beds regarded as Oligocene. The allied genus *Knightites* Saporta has two species in the Sannoisian of France.

The remarkable genus *Lomatia,* previously mentioned, has four existing species in Australia, 2 in Tasmania and 3 in Chile. As might be expected from their modern isolated occurrences there are over 30 fossil species based in some cases on associated leaves and fruits. The oldest of these are two (perhaps wrongly identified) species in the Dakota Sandstone. Eocene records include the Green River shales of North America, a Ypresian species from the south of England, an Italian species, five Australian and one Tasmanian species. There are about a dozen Oligocene species, some of which are very characteristic. They occur in the Tyrol, Saxony, Baltic Prussia and Styria, and the relatively large number of four are recorded by Dusén from Graham Land (Antarctica). There are also about a dozen Miocene species recorded from such separated areas as Colorado, Switzerland and Carniola. The wonderfully preserved leaves in the volcanic ash beds at Florissant, Colorado, from which seven forms have been described, the only known Miocene occurrence of *Lomatia* in North America, are alone sufficient to confound the sceptics.

The allied genus *Lomatites* Saporta has a Cenomanian species in Saxony and five or six Oligocene species in France. The genus *Stenocarpus* R. Brown, with 11 existing species in New Caledonia and 3 additional ranging from North Australia to New South Wales, has a single fossil species in the Oligocene of Saxony.

The genus *Persoonia* Smith has 60 existing species in Australia and one in New Zealand. The fossil record includes two widely distributed species in the Upper Cretaceous of North America; one

[22] Dusén, Wiss. Ergeb. Schwed. Südpolar. Exped., 1901–03, Bd. 3, Lief. 3, p. 7, Pl. 1, Figs. 7, 9, 11, 1908.

in the English Eocene; four in the Oligocene of Tyrol, Saxony, Styria and Greece; ten in the Miocene of France, Italy, Switzerland, Baden, Bohemia, Styria, Croatia, Carniola and Slavonia. A large number of these fossil forms of *Persoonia* are not especially convicing but certainly the three European species *Persoonia cuspidata, daphnes,* and *Myrtillus* of Ettingshausen[23] which have the leaves associated with characteristic fruits are above suspicion.

Bowerbank in his classic study of the pyritized fruits and seeds from the Island of Sheppey established a genus which he called *Petrophiloides* from its resemblance to the genus *Petrophila* R. Brown which has about 35 existing species in Australia, the majority of which are confined to West Australia. Bowerbank described several species one of which was shown by Starkie Gardner to be an *Alnus* fruit and others have been referred to *Sequoia.* Ettingshausen[24] in the study of the Sheppey fruits after careful comparisons retained three English Eocene species and the genus has also been recognized in the Sannoisian of Dalmatia and Styria.

The genus *Leucadendrites* was established by Saporta for a Sannoisian species of southeastern France from its resemblance to *Leucadendron* Herm., which has upwards of 70 existing species in South Africa.

The genus *Grevillea* R. Brown has 56 existing species confined to Australia. The fossil record includes a Cretaceous species in Australia; two Cenomanian species in Bohemia (*Grevilleophyllum* Velenovsky); three Eocene species in England, France and Italy; twelve Oligocene species mostly in southern France but also represented in Saxony, Tyrol, Bohemia, Styria and Greece; and twelve Miocene species in France, Switzerland, Bohemia and Croatia.

The genus *Embothrium* Forst., already alluded to, has four existing species in South America which range from Chile to the Straits of Magellan, and a fifth species in Australia. This widely separated occurrence is explained when the fossil record is combined with the occurrences referred to *Embothrites, Embothriopsis* and *Embothriophyllum.* To *Embothrium* are referred 8 Oligocene spe-

[23] Ettingshausen, *Sitz. K. Akad. Wiss.,* Wien, Bd. 7, 1851, pp. 718–719, Pl. 30, Figs. 6–14.

[24] Ettingshausen, *Proc. Roy. Soc. Lond.,* Vol. 29, 1879, p. 394.

cies of Styria and Greece and 4 Miocene species of Baden, Styria, Croatia and Hungary. To *Embothriopsis* Hollick a single species from the Long Island Middle Cretaceous is referred.

Embothriophyllum is used by Dusén for a single species from the supposed Oligocene of Graham Land. The genus *Embothrites* Unger has a doubtful species in the Dakota Sandstone; six Oligocene species in France, Tyrol, Styria, Carniola and Greece; and 3 Miocene species in Croatia and Bohemia.

The genus *Dryandra* R. Brown has about 50 existing species in Australia. The fossil forms have occasioned much discussion and have been referred back and forth between this genus and *Comptonia* and *Myrica*. The forms retained in *Dryandra* include a Cenomanian species in Bohemia and Moravia; an Eocene species in France; two Eocene species in Australia and an Oligocene species in Greece. The allied forms referred to the genus *Dryandroides* Unger include 5 Upper Cretaceous species in Europe and North America; an Eocene species in Tasmania; 4 Oligocene species in Italy, Tyrol, Saxony, Styria and Greece; and a Miocene species in Bohemia.

The allied genus *Banksia* Linné fil., also confined to Australia in the existing flora, has 7 Upper Cretaceous species—4 Australian and 3 in the North Temperate zone, ten Eocene species, of which 7 are Australian, 1 Alaskan (?) and 2 English; twelve Oligocene species widely distributed in Europe; 16 Miocene species equally widespread in Europe; and a Pliocene species in Italy. Three especially well marked species from the Wilcox have been referred to this genus.

The allied genus *Banksites* Saporta has a Cenomanian species in Bohemia and various Tertiary records from Europe hopelessly entangled in the literature with *Banksia, Dryandra* and *Dryandroides*. The genus *Roupala* Aublet (*Rhopala*), whose peculiarly isolated outliers in Queensland and New Caledonia have already been mentioned, is common in northern South America, extending northward to Guatemala. Fossil forms are recorded from the Cenomanian of Saxony, from the Eocene of Australia and from the Aquitanian of Switzerland. In addition Saporta described a *Rhopalospermites* from the lower Oligocene of France and a species of *Rhopalophyllum* has been described from the Upper Cretaceous of Australia and a second from the Miocene of Styria.

The geological history sketched in the preceding paragraphs is necessarily fragmentary, nevertheless I think the data are sufficient after excluding doubtful determinations to show that the family had its origin in the northern hemisphere, making its first appearance in the fossil record at the close of the Lower Cretaceous, becoming practically cosmopolitan during the Upper Cretaceous at which time it reached the Australian region from southeastern Asia. New Zealand must have already been segregated but not the land mass now represented by New Caledonia. During the early half of the Tertiary Africa and southern Europe were essentially a single floral province while in the Western Hemisphere the Proteaceæ ranged from the United States through South America and an unknown distance across Antarctica. Concomitant with the continent building and the consequent climatic changes of the Miocene the area of distribution commenced that shrinking which culminated during the Pleistocene, leaving the stranded remnants of the stock in their present widely separated quarters of the southern hemisphere. Not all the modern genera took part in this history since the local peculiarities of poor soil and rigorous climate combined with relative freedom from outside competition were the factors that stimulated a Tertiary evolution of forms in Australia in exactly the same manner as the peculiar Australian genera of Myrtaceæ and Leguminosæ were evolved.

The Wilcox species of Proteaceæ are six in number and are distributed in four genera, in addition to which a probable *Banksia* fruit is retained in *Carpolithus*. These genera are *Palæodendron, Proteoides, Knightiophyllum* and *Banksia*. The genus *Polæodendron,* not mentioned in the preceding paragraphs, was proposed by Saporta for small entire coriaceous leaves from the Sannoisian of southern France and is an entirely extinct type, sparingly represented in the Wilcox by a single species. The genus *Proteoides* was established by Heer for generalized proteaceous types which are well represented in the Upper Cretaceous floras of the embayment area as well as elsewhere. It is represented in the Wilcox by a single well-marked species confined to the Middle and Upper beds. The genus *Knightiophyllum* is proposed here for the first time for a well-marked long petioled, aquiline-toothed, coriaceous form of common occurrence at

Peryear. It is named from its resemblance to the genus *Knightia* R. Brown, a genus of few existing species confined to the Australian region but apparently represented in Europe during the Tertiary as has already been indicated.

The genus *Banksia,* with three Wilcox species, two of which are particularly well marked and a probable fruit, *Carpolithus proteoides,* is confined in the existing flora to the Australian region with about 50 species. The other genus of the tribe Banksieæ is *Dryandra* R Brown also with about 50 existing species confined to the Australian region. It is much like *Banksia* in its foliar characters. Both genera are found in abundance in the European Tertiary and undoubtedly enjoyed a more or less cosmopolitan range during the early Tertiary. Their ancestors probably entered the Australian region during the Upper Cretaceous before that country had become entirely separated from Asia, becoming adapted to the peculiar soils and climate of Australia, while the stock in the northern hemisphere appears to have been unable to stand the climatic changes and Tertiary competition and thus became extinct.

The Aristolochiales is placed by some students among the Gamopetalæ. It includes besides the Aristolochiaceæ, the two parasitic families, the Raffleisiaceæ and Hydneraceæ, altogether containing about 235 existing species, of which 205 belong to the Aristolochiaceæ, the only family of this order represented in the Wilcox flora. The genus *Aristolochia,* to which a typical fruit from the Wilcox is referred, is found in the American Upper Cretaceous and in both Europe and America during the Tertiary. There are about 180 existing species all perennial herbs or climbing vines and widely distributed in both tropical and temperate regions, about ten species being found within the United States.

The order Polygonales includes the single family Polygonaceæ with about 800 existing species segregated in about 30 genera, widely distributed. They embrace herbs, shrubs, vines and trees, with mostly cyclic flowers, and in their morphological features show some evidences of transition between the previous choripetalous alliances and the Chenopodiales. The geologic history of the family is practically unknown and it would seem that a large part of the specific variation, particularly of the temperate herbaceous forms, was rela-

tively modern. The family is represented in the Wilcox by the single genus *Coccolobis* with two species which appear to be the Eocene prototypes of the only two existing arborescent species of Polygonaceæ that reach the United States (the sea grape and the pigeon plum). The genus *Coccolobis* has about 120 existing species all confined to the American tropics and it would appear that it was of American origin. These species range from southern Florida to Mexico, Central America, Brazil and Peru and the majority are coastal forms. The two modern species which are so much like these two ancestral forms in the Wilcox, are strand types found from the Florida keys through the West Indies to the northern coasts of South America, and the conclusion is almost irresistible that the Wilcox forms enjoyed a similar range and an identical habitat.

The Chenopodiales (Centrospermæ of Engler) include ten families culminating in the Caryophyllaceæ, and containing about 3,500 existing species. They appear illy assorted and show a wide range in floral and other morphological characters. Perhaps a majority are modern types. The single family Nyctaginaceæ represents this order in the Wilcox.

The Nyctaginaceæ with about 150 existing species is predominantly American within the limits of the southern United States on the north and Chile and Argentina on the south. The genus *Pisonia* Plumier, the only genus thus far found in the Wilcox flora, is represented by three well-marked species. It has about 40 existing species chiefly in the American tropics and contains the only arborescent form of the family found within the United States. It has an extended geologic history, well-marked forms being found in the European and American Upper Cretaceous. The Wilcox species were undoubtedly strand types as are so many of the modern species, which inhabit sea beaches, the shores of salt water lagoons and marshes, the scrub of beach ridges and the jungle behind them. In the existing flora it is associated with *Pithecolobium, Reynosia, Metopium, Acacia, Bumelia, Cordia, Coccolobis, Ocotea, Fagara, Mimusops, Conocarpus, Cassia, Eugenia, Anona, Ficus,* etc., exactly as it was during Wilcox time. Species of *Pisonia* occur in the Upper Cretaceous of the Atlantic Coastal Plain (Black Creek formation) as well as in the Middle (Claiborne) and Upper (Jackson) Eocene.

The order Ranales appears to me to be a highly unnatural assemblage, which doubtless explains the prolonged discussion and wide range of opinion regarding its true status. As treated in Engler and Prantl it includes 16 families with over 4,000 existing species. While a distinct calyx and corolla are the prevailing habit this is combined with such primitive features as apocarpy and hypogyny, and by a well marked tendency to indefinite repitition and spiral arrangement of the floral members. I have removed the Lauraceæ which contain ¼ of the existing species to a place in the more evolved order Thymeleales.

The Ranales as a whole show no close filiation with previous alliances. They include forms that are more nearly Monocotyledons than Dicotyledons (Nymphæaceæ) and numerous botanists (*e. g.* Wieland, Arber, Hallier) see in them the logical zenith of evolution of the Mesozoic Cycadophytes and thus as representing the ancestral stock from which the Angiosperms were descended—apparently a most remarkable feat, except on paper, when any except floral features are taken into account.[25]

Considering as I do that the Ranalian alliance is a plexus containing unrelated elements, any extended consideration of their geologic history would be fruitless. Certain forms are well represented among the oldest known display of Angiosperms in the Middle Cretaceous. Only two Ranalian families are represented in the Wilcox flora and these two are both natural groups closely related and typically Ranalian. I refer to the families Magnoliaceæ and Anonaceæ.

The family Magnoliaceæ comprises about 70 existing species segregated into nine or ten genera, by far the largest of which is the genus *Magnolia* with about 21 species of eastern and southern Asia southern Mexico and the eastern United States. The family is mainly tropical and the bulk of the existing forms occur in southeastern Asia, the magnolias of that region being largely forms of tropical uplands.

There are numerous apparent anomalies in the distribution of the recent forms, thus none are native in Europe, although *Magnolia* per-

[25] For discussion of this theory see recent papers by Wieland, Arber and Parkin, and Hallier.

sisted in that region as late in geologic time as the early Pleistocene. Only one genus, *Drimys* Förster, occurs in South America or Australasia. There is a singular pairing of forms in southeastern Asia and southeastern North America. For example *Magnolia* has 14 species in the former region and seven in the latter: *Talauma* Jussieu has 3 species in farther India and one in the West Indies: *Liriodendron* Linné has a single species in each: *Schizandra* Michaux has species in each: *Illicium* Linné has five species in the former region and two in the latter. The general *Michelia* Linné (13 sp.) and *Kadsura* Jussieu (7 sp.) are confined to the former region and *Zygogynum* Baillon is confined to the island of New Caledonia. The leaves of all are entire and more or less elliptical with a coriaceous texture, often evergreen, and with a characteristic camptodrome venation. Of the seven species of *Magnolia* found within the limits of the United States, *Magnolia glauca* Linné ranges northward to Massachusetts and *Magnolia acuminata* Linné to New York and Ontario. About sixty fossil species have been referred to *Magnolia*. These are largely based upon leaves, although characteristic fruits, and in at least two cases, parts of flowers, have been found at various horizons. Magnolias are very abundant in both individuals and species in the Middle Cretaceous (Cenomanian-Turonian) especially in North America, where they are found along the Cretaceous Atlantic Coast from Greenland southward to Texas and in equal abundance about the borders of the advancing interior sea represented by the deposits known as the Dakota sandstone. They are much less common in Europe and the genus is either of American or Arctic origin.[26]

The Eocene records include 4 species of the Arctic region and 13 additional forms largely American, but some few European. The Oligocene, unrepresented in America by plant beds, has several European species toward its close. About eight Miocene species are recorded, of which the majority are American. The Pliocene, also practically unrepresented by plant beds in America, has furnished 5 or 6 European species and one is found in the early Pleistocene of that region. *Magnolia* seems to have been very abundant along the

[26] *Magnolia Delgadoi* Saporta, *Fl. Foss. Port.*, p. 194, Pl. 35, Fig. 5, 1894, recorded from the Albian of Portugal is almost certainly not a *Magnolia*.

shores of the extended Mediterranean sea of the Pliocene and to have subsequently been entirely exterminated in that region by the glaciation of the Pleistocene, while surviving in both North America and Asia by reason of the prevailing north and south trend of the of the mountain ranges. Some of the other genera of the Magnoliaceæ are represented by scattered fossil species but the record is too incomplete for generalizations. A survey of all the facts leads me to consider America as probably the original home of *Magnolia* and despite the massing of the existing forms in the eastern United States and their extension to Arctica in the Eocene, they probably originated in a warm-temperate or subtropical latitude, spread northward across Arctica to Eurasia, were cosmopolitan in the Tertiary, becoming restricted to the southeastern parts of Asia and North America by the aridity accompanying uplift, so well illustrated in the Eocene and later history of the Rocky Mountain and Great Plains province, and were finally killed off in Europe by the Pleistocene glaciation.

Lesquereux referred two forms from the Wilcox of northern Mississippi to *Magnolia* but these both prove to be species of *Terminalia* as Lesquereux had surmised in his preliminary studies. The genus *Magnolia* is, however, represented in the Wilcox by two large-leafed species, both of which are common to the basal Eocene of the Rocky Mountain Province. Neither show any close affinity with the antecedent Upper Cretaceous forms which are so common in the embayment area of Alabama and northeastward along the Atlantic Coastal Plain.

The family Anonaceæ contains about 700 existing species distributed among about 48 genera, only two of which are present in North America. The family is practically confined to the tropics, a single Australian species and the North American genus *Asimina* with 6 or 7 species being the only conspicuously extratropical forms. The area of maximum representation is southeastern Asia and the adjoining region of Malaysia, for while only 16 genera are confined to this region it contains over 350 species, and six additional genera (*Miliusa, Uvaria, Polyalthia, Oxymitra, Melodorum,* and *Poporvia*) with a total of over 250 species have the bulk of their species in this area. Only a single genus is confined to Australia and the bulk of the Aus-

tralian species are to be regarded as migrants from the preceding area. There are upwards of 100 species and 6 peculiar genera in tropical Africa; and America has about 200 species and 10 peculiar genera. These are all confined to the tropics except for a species of *Anona* which reaches the coast of peninsular Florida and for the genus *Asimina* with six or seven species of shrubs and small trees of the south Atlantic and Gulf States. One of these, *Asimina triloba* Dunal, is hardy as far north as New York and has the distinction of growing the farthest distance from the equator of any existing member of the family. The fossil record of the Anonaceæ is very incomplete, only the genera, *Anona* Linné and *Asimina* Adanson being known with certainty. Both of these genera are present in the Wilcox flora.

The genus *Anona* has from fifteen to twenty fossil species five of which are also represented by seeds. The oldest is a species described from the Dakota sandstone. There is a second species in the late Cretaceous or Early Eocene of the Rocky Mountain province. The flora of the Wilcox affords a glimpse into the true stage of evolution of Tertiary floras in that expanded belt of the American equatorial region which was the center of radiation of so many recent types. There were three exceedingly well marked species of *Anona* along the Wilcox coast and their leaves are very common at some localities although no seeds have as yet been discovered. I assume that these Wilcox forms had habits similar to those of the majority of the existing species, exemplified by our Florida *Anona glabra* Linné, or Pond Apple, which frequents shallow fresh water swamps, low shady hammocks, or stream borders near the coast. Other species occur in the low coppice association or on edges of brackish swamps on the Bahamas. The cultivated species, as for example the American *Anona reticulata* Linné which is planted in Guam often spreads naturally along the inner beaches, while attempts to introduce others of the most highly esteemed American species in the Orient have failed. From its prevalence among the existing species the habit of growing in wet shaded soils is evidently an old one, and since the Wilcox Anonas are associated with a strand flora, the assumption that they grew on the inner beaches or the shaded and more swampy edges of lagoons, possesses every degree of probability.

In the pipe-clays of Alum Bay which were contemporaneous with the Wilcox there are two species of *Anona,* and Engelhardt has described two species from the Eocene or Oligocene of Chili. The Oligocene record shows a species in France and a second in Saxony. In the Miocene there are two species each in England, Styria and Croatia and one each in Bohemia, Colorado and Transylvania. There is one each in the Pliocene of France and Italy, showing how modern was their extinction in the south of Europe.

The genus *Asimina* has only four or five recorded fossil species. These are all American except for a form from the Pliocene of Italy which has been referred to this genus, although I suspect that it represents *Anona,* since *Asimina* appears to have originated and been confined to the Western Hemisphere. The oldest known species is based on foliage which is found in the basal Eocene of the Rocky Mountains (Denver formation) and of the embayment (Midway Group). There is a single species based on a seed from the basal Wilcox and no other records except a form close to the modern from the late Miocene of New Jersey (Bridgeton sandstone) and the occurrence of the existing *Asimina triloba* Dunal in the interglacial beds of the Don valley in Ontario.

The order Papaverales (Rhoedales of Engler) includes six families—Papaveraceæ, Cruciferæ, Capparidaceæ, Resedaceæ, Tovariaceæ and Moringaceæ, together containing about 255 genera and 2,200 species. The Papaveraceæ and Cruciferæ are mostly herbaceous and widely distributed, largely in the North Temperate zone, and they are of relative recent evolution. The Resedaceæ is a small family largely confined to the Mediterranean region. The Capparidaceæ, Tovariaceæ and Moringaceæ are mainly tropical, the last two families consisting respectively of a single genus and two species of the American tropics and a single genus and three species, one Afric-Arabian and two East Indian.

The family Capparidaceæ with about 35 genera and 400 existing species is the only one of the order represented in the Wilcox flora. A majority of the existing species are herbaceous and they are found on all the continents in tropical and subtropical regions. Five subfamilies are recognized. Of these the Cleomoideæ and Capparidi-

odeæ are large and occur on all of the continents, with monotypic genera in North America (*Isomeris*), South America (*Stubelia Atamisquea, Belencita*), Africa (*Pteropetalum, Cladostemon*), and Australia (*Rœperia, Apophyllum*). The subfamily Dipterygioideæ has a single genus with only five or six species of Nubia, Arabia and the Punjab. The subfamily Roydsioldeæ includes about a dozen species, the genera *Roydsia* and *Stixis* being confined to India and the genus *Forchhammeria* being Mexican. The subfamily Emblingioideæ has only a single genus and species confined to Western Australia. No far-reaching conclusions regarding origin or past history can be deduced from our present knowledge of the geographical distribution of the Capparidaceæ and the fossil record is so imperfect that very little can be said regarding this history.

The following are the only fossil records known to me: F. von Müller has described somewhat uncertainly determined fruits from the Tertiary of Australia as the genera *Dieune* and *Plesiocapparis*. The latter has two species and is considered as probably a member of the section *Busbeckia* of the genus *Capparis*. Schenk has described the petrified wood of another form from the Tertiary of Egypt under the name *Capparidoxylon*. The genus *Capparis* has furnished a well-marked Wilcox species very close to the existing Antillean tree *Capparis domingensis* Sprengel. There are about one hundred existing species of *Capparis*, mostly tropical, and although found in the Eastern Hemisphere the majority occur in the American tropics, especially in Central and South America. The oldest known fossil forms are two species described by me as species of *Capparites* from the Upper Cretaceous of Alabama (Tuscaloosa formation). In addition to the Wilcox species previously mentioned, Engelhardt has described a Tertiary species from Bolivia. Many years ago Unger described a third species from the Middle Miocene of Styria but Schimper considers the latter to be a papilionaceous form. While the fossil record of *Capparis* is so meager such facts as are available would seem to indicate that it originated in the American Upper Cretaceous. Very many of the modern forms are shrubs or small trees of the strand flora and such is believed to have been the habitat of the Wilcox species.

The order Rosales includes about eighteen families[27] with over fourteen thousand existing species, the largest families being those of the Leguminosæ, and the Rosaceæ, Saxifragaceæ and Crassulaceæ. Some members of the alliance are close to the Ranales in their apocarpy, hypogyny and the indefinite repetition of certain floral members, and the order culminates in the relatively modern Papilionaceæ. Five families of Rosales are present in the Wilcox flora. Of these the three leguminous families are by far the most abundant.

The family Hamamelidaceæ consists of about nineteen genera and fifty species. Twelve of the genera are confined to the Asiatic region. One genus is doubtfully confined to Australia: Three genera are African: and three genera are common to Asia and eastern North America. The family is remarkable in containing no less than nine monotypic genera. A consideration of the existing distribution is not only of exceeding interest but also conclusive proof of an extended geologic history, which unfortunately has not yet been unravelled. Since the group is scarcely if at all represented in the existing flora of Australia or in its fossil flora, its present range over Asia would seem to have been accomplished after the land connection with Australia had been interrupted. As the only known Cretaceous fossil forms are from North America there is a probability that the group had its origin in the North American region. The fossil species are not numerous enough, however, for definite conclusions on this point.

The genus *Hamamelis* and its generalized fossil type *Hamamelites* Saporta have five species in the Dakota sandstone, one of which occurs in the Atlantic coast Upper Cretaceous (Middendorf beds of South Carolina) and another is doubtfully represented in the supposed Upper Cretaceous of Argentina (Kurtz). There are two Paleocene species in France and Belgium, and Conwentz has described characteristic flowers preserved in perfection in the Baltic Amber (Sannoisian) as *Hamamelidanthium.*

The genus *Parrotia,* with a single existing species of northern Persia and the Caucasus, has three species in the Dakota sandstone:

[27] The family Platanaceæ, which by the majority of students is referred to the Rosales, I regard as the sole survivor of an independent order, the Platanales, closely related to the Urticales.

one species in the Wilcox and Fort Union: two in the Oligocene of Europe: and two in the Miocene of Spitzbergen, Spain, France, Silesia, Austria, and Hungary. The distribution of *Parrotia* in the past as far as it is known confirms the evidence derived from *Hammamelis* for a North American origin for the family.

The third genus with a geological history is *Liquidambar,* in which upwards of twenty fossil species have been described. The oldest known forms occur in the Eocene at such widely separated points as Alaska, Oregon, Greenland and France. There are two species in the Oligocene of Asia and Europe. There are nine or ten Miocene species represented throughout Europe and North America (New Jersey to Oregon) and in eastern Asia. Three Pliocene species are represented in Spain, France, Italy, Germany, Austria, Styria and Slavonia. Typical fruits preserved in the Upper Pliocene of Germany show how late the genus flourished in central and southern Europe. Felix has described the petrified wood of *Liquidambaroxylon* from the Tertiary of Hungary. The existing *Liquidambar styraciflua* is found in the Pleistocene of West Virginia, North Carolina and Alabama and the eastern Asiatic species *L. formosana* occurs in the Pleistocene of Japan. The genus *Corylopsis* also occurs in the post-Miocene deposits of Japan.

The family *Rosaceæ* includes about 90 genera and over 1,300 existing species, widely distributed and mostly in temperate regions. Some of the genera like *Cratægus* seem to be undergoing saltation at the present time and hundreds of supposed species have been described in the past few years. The tribe Chrysobalanoideæ is confined to the tropics and the Neuradoideæ to the subtropics of Africa and southwestern Asia. All of the other tribes of Rosaceæ are widely distributed and their modern and fossil distribution is without especial significance for the present discussion.

The only genus represented in the Wilcox is *Chrysobalanus* with two species that are evidently the prototypes of the still existing forms. The latter are but two or three in number and as shrubs or small trees they inhabit the sandy shores in the maritime regions of Florida, tropical America and western tropical Africa.

The Leguminosæ as now segregated into 4 families constitutes

the largest alliance among the Choripetalæ (Archichlamydeæ), and next to the Compositæ the largest angiospermous group, with over 9,000 existing species segregated among about 450 genera.

There is a well-defined floral progression from the family Mimosaceæ with its actinomorphic flowers and numerous, usually free, stamens, through the Cæsalpiniaceæ, culminating in the numerically greatest group the Papilionaceæ with its strongly zygomorphic flowers and coalescent stamens, comparable with the like culmination in floral evolution of the Orchidaceæ among the Monocotyledonæ.

The Mimosaceæ, with about 30 genera and 1,400 existing species, are massed in the tropics of both hemispheres. None of the subfamilies are confined to a single continent but comparatively few genera occur in more than two continental areas and half the genera are restricted to a single continent. Asia and Australia each have two peculiar genera, Africa has four and America has seven. America also leads in number of species, about half the total of the family being present in the New World. Australia comes next with over 300, Africa next with upwards of 300 and Asia last with about 100. In the eastern United States there are only three genera and five species, none of which are arborescent. In the Gulf States the numbers have increased to 14 genera and 44 species.

The Cæsalpiniaceæ with about 90 genera and 1,000 species is also mainly tropical with a massing of forms in the American tropics where there are over 600 species and 37 peculiar genera, the subfamily Sclerolobieæ being entirely American and containing numerous monotypic genera. Asia and Africa each have about 150 species. There are, however, only 10 Asiatic genera as compared with 17 African. There are but three Australian genera and less than 100 species. In the eastern United States there are 5 genera and eleven species. Three of the genera, *Cercis, Gleditsia* and *Gymnocladus* are arborescent. In the southern states there are 11 genera and 44 species.

The Papilionaceæ have about 320 genera and 6,600 species. America leads in the number of peculiar genera having 82 while Asia leads in the number of species with about 1,700. Africa has 47 peculiar genera and about 1,600 species. Australia has 38 pecu-

liar genera and about 1,000 species. Asia has 33 peculiar genera, while Europe with 7 peculiar genera and about 700 species is less rich in both species and genera than any other continent. None of the subfamilies are confined to a single contintent but some of the tribes are, the Lipariinæ being South African and the Bossiæinæ being Australian, while 20 of the 27 genera and all but 63 of the 436 species of the subfamily Podolyrieæ are Australian. Two genera in this subfamily are American, 2 African, 1 Asiatic, 1 Mediterranean (Eurasia) and 1 common to North America and Asia.

In the eastern United States there are 46 genera and 194 species of Papilionaceæ, the genera *Cladrastis* and *Robinia* being arborescent. In the southern states there are 55 genera and 318 species. Sargent's "Manual of North American Trees," which includes many tropical forms of the Florida Keys, enumerates for the Leguminosæ as a whole only 34 arborescent species for North America in 17 genera.

In Grisebach's flora of the British West Indies the Leguminosæ outnumber all other families of flowering plants with 262 species. The same is true of Urban's flora of Porto Rico where they number 136 species.

The Leguminosæ found in the Wilcox deposits number over fifty species, many of which are individually abundant. They represent the families Mimosaceæ, Cæsalpiniaceæ and Papilionaceæ, the fourth family of the leguminous alliance, the Krameriaceæ, being a small herbaceous group of the New World of very late, probably of recent, evolution.

Of these fifty-odd Wilcox species eleven are referred to the Mimosaceæ, 26 to the Cæsalpiniaceæ and 20 to the Papilionaceæ. Definitely recognized genera are named in the usual way. Forms usually identified as species of *Acacia* (as for example most of those so named by Heer, Ettingshausen, Unger, etc.) which are referable to the Mimosaceæ but not to the genus *Acacia* as commonly understood are referred to the form-genus *Mimosites*. Forms not certainly identified as *Cæsalpinia* but referable to the Cæsalpiniaceæ are classed under the form-genus *Cæsalpinites* while a considerable number of *Gleditsia*-like forms of both leaves and pods are described in

the genus *Gleditsiophyllum,* a form-genus proposed by me in the first instance for an Upper Cretaceous form from North Carolina. There is a certain unavoidable duplication in the giving of specific names to unattached pods and leaflets since in some cases they may belong to the same botanical species. I have followed this method, however, in all instances where I was not sure of such a relationship.

The Mimosaceæ of the Wilcox are referred to four genera. The genus *Acacia* represented by a single indisputable species in which the leaves are reduced to phyllodes is of great interest since in the existing flora the 450 species are largely confined to the Australian region. The section Phyllodineæ to which the Wilcox species is referred has about 300 existing species which are confined to Australia and Oceanica although in Eocene times they were also present in Europe. It is a curious commentary on the modern character of the earlier Tertiary floras that the reduction of foliar organs and the habit of phyllody, often correlated with modern arid conditions, should have really been developed in these early floras.

The genus *Inga,* represented in the Wilcox by four well marked species, has upwards of 150 species in the existing flora, all of which are confined to the American tropical and subtropical regions. Its geological history is for the most part unknown although it appears to be represented in American Upper Cretaceous floras by *Inga cretacea* Lesquereux which occurs in the Dakota Sandstone and in the Tuscaloosa formation of Alabama. Ettingshausen has described a species from the Cenomanian of Saxony (*Inga Cottai*) and the European Miocene has furnished two or three species, while Engelhardt has described a Tertiary species from Bolivia.

In the genus *Pithecolobium,* which has two Wilcox species and belongs to the same tribe as *Inga* (Ingeæ), while the majority of the 100 or more existing species are American there are over a score in tropical Asia and a few in tropical Australia and Africa. With the exception of a Tertiary species from Bolivia I do not know of other fossil occurrences.

The genus *Mimosites,* with four Wilcox species, represents trees of the *Mimosa* type very abundant in recent species referred to several genera which are either American, Asian, Australian or African,

and abundantly represented in European Tertiary floras. Its Cretaceous ancestry is hidden among the species of leaflets referred to the form-genus *Leguminosites.* The genus *Mimosa* which is apparently most like the Wilcox *Mimosites,* has over 300 existing species and these are for the most part confined to the warmer parts of America, although they are represented in Asia, Africa and Australia.

Except for the family Lauraceæ the Cæsalpiniaceæ with 26 species is the largest family in the Wilcox flora and it is certainly a fact of considerable interest that the massing of the modern species in the American tropics should be foreshadowed by their numerical abundance on this continent as early as the Lower Eocene.

The Wilcox genera are five in number of which the largest is *Cassia* with twelve species. *Cassia* is the largest Wilcox genus except *Ficus,* and all of its species find their modern counterparts in existing species of tropical and subtropical America, many of which are mentioned by name in the systematic part of this work. Numerous as are the Wilcox species of *Cassia* there was apparently greater specific differentiation in contemporaneous European deposits since Ettingshausen records 15 species in the flora of Alum Bay (Ypresian of Isle of Wight). *Cassia* has between three and four hundred existing species found in the warmer temperate and tropical regions of all the continents and especially abundant in tropical America. Their place of origin is unknown since they make their appearance in the Upper Cretaceous almost simultaneously in New Zealand, Australia, Bohemia, Saxony, Greenland, the Atlantic Coastal Plain and the Dakota Group of the Rocky Mountain province. Upwards of one hundred fossil species are already known. Nor does the Eocene distribution shed any light on the early history of the genus since species occur in such widely separated regions as North America, Europe and Australia. There are numerous Oligocene and Miocene species, the Oligocene records being confined to Europe and Africa and the Miocene records being confined to Europe and North America. *Cassia* was abundant along the shores of the Pliocene Mediterranean of Europe and 4 species are recorded from South American beds which are thought to be of Pliocene age. Pleistocene species

are recorded from Maryland and the East Indies (Java) associated in the latter region with *Pithecanthropus erectus* Dubois. One fact is certain, the genus has been a part of the American flora since the dawn of the Upper Cretaceous, and several of the Wilcox species are the undoubted prototypes of existing forms of the American tropics.

The genus *Cercis,* with a single Wilcox species, makes its first recorded appearance in geological history in the Wilcox species, in the three species recorded from the Ft. Union deposits of the Rocky Mountain province and a fourth species found in the Ypresian of the Paris basin, so that its appearance was practically contemporaneous in France and Tennessee. It continues on both continents down to the present being even represented in the Pleistocene of both. The modern species number five or six and inhabit the warmer temperate regions of America, Europe and Asia.

There is one species of *Cæsalpinia* in the Wilcox and it is almost identical in character and habitat with *Cæsalpinia bahamensis* Lamarck of tropical America. The existing species number about two score of the tropics of both hemispheres. *Cæsalpinia* is recorded first from the Upper Cretaceous of the Atlantic Coastal Plain and it seems probable that it originated on this continent and reached Europe during the Eocene by way of the Arctic region, since it is common in the Oligocene, Miocene and Pliocene of the latter continent.

Four Wilcox species are referred to the form-genus *Cæsalpinites.* These represent true forms of *Cæsalpinia* or of allied genera in this family, one almost certainly representing the genus *Parkinsonia,* a small genus which occurs in the European Oligocene but which in the existing flora is confined to the warmer parts of North America and South Africa. Fossil forms referred to *Cæsalpinites* include about twenty of the European Oligocene and Miocene.

The genus *Gleditsiophyllum* makes its appearance in the Upper Cretaceous of the Carolina region. It is represented by eight species of leaves, leaflets and pods, often abundantly preserved, in the Wilcox deposits. Their relation to modern genera is uncertain, although they were evidently much like *Gleditsia.*

Two genera of Cæsalpiniaceæ which I confidently expected to find in the Wilcox and which must have been present during this time in southeastern North America are *Hymenæa* and *Bauhinia*. The former is confined to the American tropics in the existing flora where it has about eight species. It is represented by characteristic forms in the Upper Cretaceous of Alabama. The genus *Bauhinia* which has about 150 existing species of the tropics of both hemispheres has several especially characteristic forms in the Upper Cretaceous of southeastern North America (New Jersey, Maryland, Alabama).

The family Papilionaceæ which comprises over two thirds of the existing Leguminosæ undoubtedly represents the culmination of evolution in the alliance. The bulk of the family, especially the numerous herbaceous genera, are unquestionably of comparatively recent origin. In spite of this fact the family has twenty species in the Wilcox. These are distributed among six genera, of which *Dalbergites, Carpolithus* and *Leguminosites* are form-genera, while the other three are still existing. The largest genus is *Sophora* with seven species, one of which, evidently a strand type similar to and comparable in habitat with the cosmopolitan strand plant *Sophora tomentosa* Linné of the existing tropical flora, is very abundant in the Wilcox deposits. There are about 25 existing species of shrubs and small trees referred to this genus. They are scattered over the warmer parts of both hemispheres and are found on all tropical seashores. About a dozen fossil species are known. In addition to North America they are found in both Europe and Asia during the Eocene, a single form from Alum Bay (Ypresian) being contemporaneous with the Wilcox species and the others being later. While few species have been described the genus is widely distributed in the European Miocene where *Sophora europæa* Unger was a common coastal form of the Mediterranean region throughout the Miocene and into the Pliocene.

Four species, three based on leaflets and the fourth on a characteristic pod, represent the genus *Dalbergia* in the Wilcox flora. Two additional species whose generic relations are not so certain are referred to the genus *Dalbergites*. The existing species of *Dalbergia*

number about eighty forms found in the tropics of both hemispheres, and all show a strong generic similarity in their foliar characters. Over two-score fossil forms are known. The earliest of these occur in the Atlantic Coastal Plain and western Greenland so that there is a strong possibility that the genus was of American origin. If this theory was correct they must have undergone a rapid radiation since in the Eocene they are not only found in America and the Arctic but in Europe and Australia. The Alum Bay beds of the Isle of Wight (Ypresian) which I regard as contemporaneous, in part at least, with the Wilcox, contain according to Ettingshausen, six species of *Dalbergia*. European deposits furnish about a dozen Oligocene species and still more numerous Miocene species. *Dalbergia primæva* Unger, *D. retusæfolia* Heer, *D. hæringiana* Ettingshausen and *D. bella* Heer are widespread coastal forms of the European Tertiary, some of them ranging from the late Oligocene through the Miocene and into the Pliocene.

The genus *Canavalia* is represented in the Wilcox by a fine species undoubtedly ancestral to the existing *Canavalia obtusifolia* (Lamarck) De Candolle, a widely distributed tropical strand plant. A second species is less commonly represented and not as certainly identified. The genus contains about a dozen existing species of the tropics of both hemispheres but has not been heretofore found in the fossil state.

The Wilcox forms referred to *Leguminosites* cannot be dealt with satisfactorily since they represent pods and leaflets of this alliance whose generic relations are uncertain. The form-genus was proposed first by Bowerbank for the pyritized remains from the Island of Sheppey (London Clay), and two of his species are tentatively identified in the Wilcox. Subsequently many species have been described. They range in age from the Middle Cretaceous to the Pliocene. Saporta describes the oldest form in the Albian of Portugal. They are present in the Cretaceous of Australia, the Cenomanian of Saxony, the Atane and Patoot beds of Greenland, and the Atlantic Coastal Plain Cretaceous from Marthas Vineyard to Alabama. They are common in the Arctic Eocene, occurring also in Australia, America, Europe and Asia. Oligocene records in-

clude Europe and Antarctica, Miocene records are confined to America and Europe and Pliocene records include southern Europe and Japan.

While the foregoing analysis leaves a great many points in the history of the Leguminosæ unsolved it serves at least to show that the Wilcox forms are all represented and would find a congenial habitat in the present day American tropics and that thus early some of the main features of their present day development had been differentiated.

The most similar fossil display of these forms is to be found in the Ypresian flora of Alum Bay on the Isle of Wight, which unfortunately have never been described or figured, but of which Ettingshausen[28] published an analysis and enumeration in 1880. Another very similar display of forms is that described by Engelhardt from the Tertiary of Cerro de Potosi in Bolivia.[29] The exact age of the latter has never been determined although its resemblance to this part of the Wilcox flora suggests the possibility that it is Eocene instead of Pliocene, which later has been assumed to be its age. This may, however, simply be a reflection of the similarity between the Leguminosæ of the Embayment area in the Lower Eocene and those of subsequent periods in the American tropics.

The order Geraniales includes 21 families, with upwards of ten thousand existing species, of which nearly one half belong to the family Euphorbiaceæ. The other large families in the order of their size are the Rutaceæ, Meliaceæ, Malpighiaceæ, and Polygalaceæ each with over five hundred existing species, while the Geraniaceæ, Oxalidaceæ, and Burseraceæ each have over three hundred existing species. The alliance is mainly cyclic in the character of its floral members, starting with isocarpic forms and progressing in the direction of reduction in the number of carpels. The phylogenetic importance of the characters by which the Geraniales as an order is separated from the evidently allied Sapindales is not great and in some respects the order is apparently not a natural one. Six families of Geraniales have been recognized in the Wilcox flora. The

[28] Ettingshausen, *Proc. Roy. Soc. Lond.*, Vol. 30, 1880, pp. 228–236.

[29] Engelhardt, *Sitz. naturwiss. Gesell. Isis in Dresden*, 1887, Abh. 5, pp. 36–38, 7 Figs.; *Ibid.*, 1894, Abh. 1, pp. 3–13, Pl. 1.

first of these, the Rutaceæ, consists of about 111 genera and over 900 existing species widely distributed over the warm temperate and tropical regions of the earth. The fruits are capsules, samaras or drupes and the leaves which may be simple or compound are usually glandular punctate. While there are 34 genera with 127 species confined to America the family makes its greatest display in the Old World, Africa having 16 peculiar genera with 196 species and Australia 28 peculiar genera with 185 species. In addition to 6 genera with 7 species confined to the Asiatic Mainland there are 19 genera with 167 species found distributed from southeastern Asia through Malaysia greater or less distances, in some cases to New Zealand and Polynesia. The only truly cosmopolitan genus is *Fagara* with upwards of 150 existing species and represented in all tropical countries. The tribe Boronieæ with 18 genera and 158 species is confined to Australia and New Zealand; the Diosineæ with 11 genera and 181 species is confined to South Africa; and the Cusparieæ with 16 genera and 83 species is confined to tropical America. All of the other rather numerous tribes are represented in more than one continental region.

The family contains the remarkable number of 42 monotypic genera and while many of these may be regarded as of recent evolution, as for example a number of those of Australia, the isolated occurrences of many of the others indicates that they are of great age and once occupied intervening areas.

There are only twelve known fossil genera, or only about 10 per cent. of the existing genera, so that little can be said of the fossil history of the family. The oldest genus is *Citrophyllum* Berry represented by very characteristic leaves with alate petioles found in the Dakota sandstone of the Rocky Mountain province and from New Jersey to Alabama along the Atlantic coast in the Raritan, Magothy, Middendorf and Tuscaloosa formations. There is a second species of *Citrophyllum* in the Wilcox and a third in the overlying Claiborne. These forms are very similar to the leaves of recent members of the Aurantioideæ and undoubtedly represent ancestral forms. The genus *Dictamnus* Linné with a single existing species widely distributed in Eurasia, has furnished a fossil form in the Pliocene of France and a second in the Pleistocene of Japan. Unge

in 1850 described petrified wood from the Aquitanian of Greece as *Klippsteinia medullaris* referring it to the Aurantioideæ.

The genus *Amyris* (P. Browne) Linné has about a dozen existing species in the Antilles and Central America, two of which reach the coast of southern Florida. A fossil form is recorded by Unger from the late Miocene (Sarmatian) of Hungary. This determination is not conclusive however although Unger had both the leaves and fruit of *Protamyris berenices*. Unger also described the supposed ancestral genus *Protamyris* to which he referred four species from the Aquitanian of Kumi and the Miocene of Croatia. These are not especially convincing and both Ettingshausen and Schenk consider *Protamyris radobojana* Unger to represent a species of *Cedrela*.

The genus *Xanthoxylum* Linné with nine or ten existing species of eastern Asia and North America has been a favorite receptacle for fossil forms of Rutaceæ. About a score of species have been described, the oldest coming from the basal Eocene of New Mexico (Raton formation) while a second Eocene species is recorded from the Bartonian of France. Engelhardt has described two Eocene or Oligocene species from Chili. There are four Oligocene species, two in France and two in Prussia. There are about thirteen Miocene species, widely distributed and represented in California, Colorado, Spain, France, Switzerland, Baden, Bohemia, Croatia and Hungary. The two Pliocene species represent France and Asia Minor and one of the recent species is found in the Pleistocene of Japan. It seems probable that *Xanthoxylum* was derived from *Fagara* through a loss of the floral calyx and by adaptation to less tropical climatic conditions.

The genus *Fagara* Linné is substituted for *Xanthoxylum* by many recent systematists, although I prefer to consider it as the ancestral stock and in the older sense as including the 150 cosmopolitan tropical species while *Xanthoxylum* includes the extratropical forms of Asia and North America. Undoubtedly several if not all of the fossil forms described as species of *Xanthoxylum* are more properly referred to *Fagara* although none have heretofore been described under this name. The Tertiary flora of southeastern North America contains several very characteristic forms of this genus. The oldest

are three species from the Wilcox Group. There is another in the overlying Claiborne Group. The Vicksburg Group has furnished a very common form with several well-marked varieties some of the leaves of which show their glandular punctate character beautifully preserved. Still another form is found in the Apalachicola Group of Florida.

The genus *Ruta* Linné with upwards of 100 existing species mostly of Eurasia although present in Africa and South America, has furnished Menzel (1913) with characteristic capsules in the Aquitanian of Rhenish Prussia.

The genus *Phellodendron* Rupr. with two existing Asiatic species is represented in the Aquitanian of Rhenish Prussia by fruits (drupe). Engelhardt has described species of *Ticorea, Pilocarpus* and *Erythrochyton* from the early Tertiary of Chili.

The remaining genus with fossil representation is *Ptelea* Linné which has 7 or 8 existing species[30] confined to the United States and Mexico. The fossil forms are represented by both leaves and characteristic fruits. The oldest comes from the Arctic Eocene. There is a species in the Oligocene of Italy and six Miocene species, occurring in Colorado, France, Switzerland, Carniola and Hungary. A Pliocene species is recorded from Italy. Obviously the record will have to become much less fragmentary before any creditable conclusions can be drawn respecting the place of origin and geologic history of the Rutaceæ.

The family Simarubaceæ (often spelled Simaroubaceæ) includes about 28 genera and upwards of 150 existing species of shrubs or trees with pinnate leaves and drupaceous fruits, confined chiefly to the tropics and the warmer parts of the northern hemisphere. Only three of the existing species reach as far northward as the coast of southern Florida. The family is still represented on all the continents except Europe. Two genera with four species are confined to Asia; 3 genera with 4 species are confined to Australia; 4 genera with 6 species are confined to Africa and 9 genera with 71 species are confined to America. The most widespread species is the monotypic *Suriana maritima* Linné a cosmopolitan tropical strand plant occurring on the dunes, keys and coastal hammocks of southern Florida.

[30] Greene has recently described very many poorly established new species.

The only genus represented in the Wilcox is *Simaruba* Aublet, which has furnished a single species, *Simaruba eocenica* Berry, closely resembling the existing *Simaruba glauca* De Candolle which is found along tropical coasts from southern Florida to Brazil.

The only other genus with a geological history is *Ailanthus* Desf. which has 7 existing species of eastern Asia and the East Indies.[81] The fossil species number about fifteen. There are two in the Eocene of Wyoming and Oregon; eight in the Oligocene of France, Alsace, Styria and Prussia; and five in the Miocene of France, Switzerland, Baden, Italy and Colorado. While in the absence of collateral evidence that the Eocene occurrences in North America have any significance regarding the origin of the genus it is an interesting speculation that the genus originated in North America and subsequently reached Asia by way of the Eocene land connection across Behring straits. Certainly the genus lingered on this continent, as is evidenced by its presence at Florissant, as late as the Middle Miocene.

The family Meliaceæ contains about 42 genera and about 680 existing species of shrubs and trees with pinnate leaves. The vast majority are found within 30 degrees of the equator although they reach 40° north in eastern Asia and 40° south in New Zealand. Moreover the China berry (*Melia azedarach*) has been cultivated from time immemorial in all Mediterranean countries, and throughout the southeastern United States since its settlement, and is perfectly hardy. There are no temperate outliers however. While the Meliaceæ occupy a greater continuous area in South America where over 41 per cent. of the existing species occur, this large number of species (about 285) represent only 19 per cent. of the known genera. There are some remarkable similarities between the species of the American tropics and those of West Africa. Thus the two small genera *Swietenia* and *Carapa* are represented in both areas and *Carapa procera* is even said to be common to the two. Moreover the genus *Guarea* which has about 80 species in the American tropics has three in West Africa. The larger number of genera are found in the S. E. Asiatic region and the number of genera and their mutual

[81] *Alianthophyllum* Dawson with a single species is described from the Eocene (?) of British Columbia.

affinities decrease from Asia toward Africa and also through Polynesia. A number of genera (*Toona, Xylocarpus, Cipadessa, Melia*) extend from Africa through Asia to Malaysia. Two genera are peculiar to Australia (*Synoum, Owenia*) and two to Polynesia (*Vaveæ, Meliadelpga*). There are thirteen monotypic genera of which six are African and seven Asiatic. From the distribution of the existing species De Candolle[32] infers that southern Asia is the center of radiation of the family. I am inclined to think however that the reverse is probably true since the oldest known forms, except the entirely doubtful Cedrelospermites of Saporta from the Valanginian of Portugal, are American, and the widespread existing American representation of the family seems to comprise the specifically multiplied descendents of the original stock already represented in the Wilcox flora.

The Asiatic genera would represent immigrants into that area or forms evolved there. The Polynesian and Australian forms are much localized derivatives of the Indian stock and unless the peculiar species of New Caledonia could not reach that region except by a land connection it may be inferred that this Asiatic radiation was relatively recent.

The fossil species are unfortunately few in number. So far as I know the only fossil species of *Carapa* is that found in the Wilcox. Its occurrence in the early Eocene is at least a factor in explaining its present distribution in both the American and West African tropics. The fact that *Carapa procera* is common to these two areas may suggest that all of the African species are recent immigrants, but it is more probable that there are unrecognized specific differences in this form in the two areas and that the present disconnected distribution is an example of survivors from the early Tertiary radiation. Another genus with a modern distribution like Carapa is the genus *Moschoxylon* Jussieu (made a section of *Trichilia* Linné by Harms in Engler and Prantl) which has about 60 species of tropical America and West Africa. This has furnished two fossil species described by Engelhardt from the early Tertiary (Eocene or Oligocene) of Chili. The genus *Cedrela,* sometimes made the type of an

[32] De Candolle, C. de, "On the Geographical Distribution of the Meliaceæ," *Trans. Linn. Soc. Lond.*, 2 ser., Bot., Vol. 1, 1880, pp. 233–236, Pl. 30, 31.

independent family, the Cedrelaceæ, has four Wilcox species, Eocene prototypes of existing American species. This genus with 9 or 10 species is confined to America in the existing flora and is only known outside this area in two species from the Miocene of Croatia which Unger referred to *Cedrela* and an undescribed *Cedrela* recorded by Ettingshausen from the Ypresian of the south of England. Saporta has, however, recorded six species of *Cedrelospermum* from the Sannoisian of southeastern France. The fossil record of these three genera *Carapa, Moschoxylon* and *Cedrela,* brief as it is, shows clearly that the Meliaceæ are not a modern element in the flora of the American tropics but one that was already well differentiated in the early Tertiary.

The remaining fossil references to this family comprise *Meliaceæcarpum* based on capsules from the Aquitanian of Prussia which Menzel their describer compares with those of the genera *Dysoxylum* and *Guarea.* F. von Müller has described *Rhytidotheca* and *Pleioclinus,* two supposed meliaceous genera based on fruits, from the Pliocene of Australia.

The family Humiriaceæ is a small one, comprising only three genera and a score of species of shrubs and small trees all of which are confined to the American tropics except a single species found in tropical West Africa, a distribution suggesting a history comparable with that just suggested for *Carapa, Moschoxylon* and *Cedrela.* The only known fossil species is one from the Wilcox very close to the existing *Vantanea paniculata* Urban of northern South America.

The family Malpighiaceæ, confined to tropical and subtropical countries, contains about 55 genera and 650 existing species, many of which are scandent, including some of the finest lianas of the tropics with stems 2 dcm. in diameter. Others are shrubs and trees. The leaves are opposite and simple and the fruits drupaceous, capsular, or nutlike, and often winged. The only species that reaches the United States is *Byrsonima lucida* (Swartz) De Candolle, a small evergreen tree of the Florida keys.

The family is predominantly American in its distribution, over 67 per cent. of both genera and species being confined to the Western Hemisphere (37 genera and 440 species). The genera are all local in the sense that none occur in more than one continental area.

Of the two subfamilies into which the family is divided—the Pyramidotoræ and Planirotæ, the latter with two tribes Galphimieæ and Malphighieæ are entirely American. Of the three tribes into which the Pyramidotoræ is divided the Tricomarieæ are entirely American, the Hiræeæ have 3 genera and 23 species confined to Asia, 3 genera and 12 species confined to Africa, a genus with 12 species ranging from Malayasia to Australia, and 9 genera with 151 species confined to America. The remaining tribe, the Banisterieæ, has a monotypic genus in Asia, 2 genera and 15 species in Africa, a single genus with 7 species ranging from the East Indies to Australia and 11 genera with 247 species confined to America.

There are 21 monotypic genera distributed as follows: *Microsteira* confined to Madagascar: *Flabellaria* confined to Africa: *Caucanthus* confined to Arabia: *Brachylophon* confined to farther India: *Mezia, Diplopteris, Lophopteris, Clonodia, Coleostachys, Blepharandra, Lophanthera, Verrucalaria, Pterandra, Acmanthera, Diacidia,* and *Glandonia* confined to Brazil, Guiana and Venezuela: *Henleophytum* confined to Cuba: *Lasiocarpus* and *Echinopteris* confined to Mexico: and *Tricomaria* and *Mionandra* confined to Argentina.

Monotypic genera in general are susceptible of two interpretations, i. e., they represent either the last survivors of a long line as in the case of the *Ginkgo, Sassafras,* etc., or they represent relatively recent specializations. In the case of the foregoing monotypic genera it seems probable that the majority are the result of relatively recent evolution since there is nothing in their character or distribution to suggest any extended geologic history and none have been found in fossil floras.

The fossil record is most incomplete. No forms are known from the Upper Cretaceous for although Ettingshausen recorded a species of *Malpighiastrum* and one of *Banisteriophyllum* from the Upper Cretaceous of Australia, those identifications are open to the most serious question and I do not consider them of any weight in a discussion of this kind. The family is certainly represented in the lower Eocene by five species of *Malpighiastrum, Hiræa* and *Banisteria* in the Ypresian of the south of England and by five species of *Hiræa* and *Banisteria* in the Wilcox flora, based upon both leaves and characteristic fruits. There are also doubtful species of *Malpighias-*

trum and *Banisteriophyllum* described from the Eocene of Australia by Ettingshausen. Thus there is no direct geologic evidence of the place of origin of the family. The fact that it is so predominantly American at the present time and that only two genera have reached Australia from the East Indian region and that two of the American genera appear in the northward extension of the early Eocene flora of the American tropics during the Wilcox and are as ancient as any certain records of the family anywhere, renders the conclusion that the family originated in equatorial America an extremely probable one. With the exception of the Wilcox records enumerated above nearly all of the fossil records relate to Europe, and these may be briefly enumerated.

The genus *Malpighiastrum* of Unger has about 30 recorded species. These include the doubtful Upper Cretaceous and Eocene species previously mentioned as recorded by Ettingshausen from eastern Australia; 3 Ypresian species from the south of England; eight Oligocene species in France, Italy, Dalmatia, Styria and Transylvania; about 15 Miocene species in Italy, Prussia, Bohemia, Croatia and Transylvania; and two Pliocene species in Italy.

The genus *Heteropteris* Jussieu, with about 90 existing species ranging from Mexico and the Antilles to Bolivia and Brazil, has a late Oligocene species in Transylvania and two Miocene species in Styria and Croatia.

The genus *Hiræa* Jacq., with about 25 existing species ranging from Mexico and the Antilles to Peru, has furnished about ten fossil species, based for the most part on the winged fruits. There is a species in the Ypresian of southern England and a characteristic fruit in the Wilcox; four Oligocene species in the Tyrol, Styria and Transylvania; three Miocene species in Baden, Styria and Transylvania; and a Pliocene species in Brazil.

The genus *Tetrapteris* Cav., with about 60 existing species ranging from the West Indies and Mexico to southern Brazil and Bolivia, has furnished a fossil species in the Oligocene of Styria and three Miocene species in Bohemia, Styria and Croatia.

The genus *Stigmatophyllon* Jussieu, with about 45 existing species found in the Bahamas and Antilles and along the east coast of America from Mexico to Uruguay, has furnished Saporta with a

somewhat doubtful form from the Upper Oligocene of France. Similarly the genus *Byrsonima* L. C. Rich., with 90 existing species ranging from the Bahamas and Mexico to southern Brazil and Bolivia has been recorded by Massalongo from the early Pliocene of Italy, but the identification is extremely doubtful.

The genus *Banisteria* Linné contains about 70 existing species of climbing or scrambling shrubs ranging from the West Indies throughout tropical South America. It is represented by four species based upon both leaves and fruits in the Wilcox; there is a Ypresian species in the south of England; four Oligocene species in France, the Tyrol, Alsace and Styria; and four Miocene species in France, Switzerland and Croatia.

The genus *Banisteriophyllum* Ettingshausen with a single Upper Cretaceous and an Eocene species in eastern Australia I regard as of very doubtful affinities. Schenk also states that wood of a malpighiaceous type occurs among the silicified woods from the Oligocene of the Island of Antigua.

The family Euphorbiaceæ is sometimes made the type of a distinct order, the Euphorbiales, although the significance of the characters by which it is segregated from the Geraniales is not obvious. It is an exceedingly large alliance with about 220 genera and 4,000 existing species (Pax, 1890) of herbs, shrubs and trees, widely distributed throughout the tropical and temperate zones. The genus *Euphorbia* with over 700 species is perhaps the most widely distributed genus in the family. A very large number of the recent species, particularly those of xerophytic character so closely simulating the Cactaceæ, are of relatively recent evolution.

In such a multiplicity of existing genera and species any effort to trace the larger features of distribution would occupy more space than it is worth in the present connection. Four arborescent genera with five species reach the United States in the Florida region, and several additional are naturalized in that area. A considerable, but relatively insignificant, number are recorded during the Upper Cretaceous and Tertiary. The fossil records will, however, have to be greatly increased before they can be said to shed any definite light on the geological history of the family. Enough is now known,

however, to abrogate the statement made by Schenk[33] and quoted by Pax[34] that there is no certain evidence of the existence of the Euphorbiaceæ during the Tertiary. The following genera have been recorded as represented in the fossil state.

Euphorbia with a single species based upon a fruit described by Heer from the Swiss Miocene: *Euphorbioides* based on an inflorescence described by Wessel and Weber from the Aquitanian of Rhenish Prussia; the genus *Euphorbiophyllum* with several species to be noted presently; I have described a very characteristic species of *Manihotites* from the Upper Cretaceous of Georgia; the genus *Crotonophyllum* has several Upper Cretaceous and Eocene species; *Cluytia* is reported from the Eocene of the Isle of Wight and the Oligocene of Saxony and Rhenish Prussia; the following genera each with a single species were identified by Ettingshausen from the Miocene of Bohemia, *i. e., Adenopeltis, Baloghia, Omalanthus* and *Phyllanthus.* Conwenz has described a euphorbiaceous flower from the Baltic Amber (Sannoisian) as *Antidesma maximowiczii* and Felix has described petrified wood from the Tertiary of the U. S. of Columbia as *Euphorbioxylon. Hura*-like fruits are also recorded by Knowlton from the lower Eocene (Raton formation) of New Mexico. Engelhardt has recorded species of *Omphalea* Linné, *Tetraplandra Baillon* and *Mallotus* Lour., from the early Tertiary of Chili.

While difference of opinion regarding the determination of some of these records is justifiable I regard *Manihotites, Euphorbiophyllum, Crotonophyllum* and *Euphorbioxylon* as definite evidence of the existence of the Euphorbiaceæ during the Upper Cretaceous and Tertiary.

The Wilcox species are five in number and are referred to the genera *Crotonophyllum, Euphorbiophyllum* and *Drypetes.* The genus *Crotonophyllum* was proposed by Velenovsky for a well-marked species from the Cenomanian of Bohemia. I have described a second species from the Upper Cretaceous of South Carolina. Two species are recognized in the Wilcox and of these *Crotonophyllum*

[33] Schenk, "Palæophytologie," pp. 594–597, 1890.

[34] Pax, in Engler and Prantl's "Naturlichen Pflanzenfamilien," 1890.

eocenicum Berry may be successfully compared with a number of the six hundred existing species of *Croton* which is so abundantly represented in tropical America. Comparisons are especially close with *Croton eluteria* (Linné) Bennett which is found in the low coppice of the beach ridges throughout the Bahama islands.

The genus *Euphorbiophyllum* was proposed by Ettingshausen in 1853 for several species from the Sannoisian of the Tyrol. Altogether over a dozen species have been described by Ettingshausen, Saporta and Engelhardt. These have been compared with the existing, mostly tropical American, species of *Styloceras, Sapium, Stillingia, Adenopeltis, Exoecaria, Colliquaja,* etc. The oldest comes from the Cenomanian of Portugal and a second Upper Cretaceous species occurs in the Turonian of southern France. In the Eocene there is a species in West Greenland, a second on the Island of Sheppey (Ypresian) and a third in the Paris basin (Lutetian). Five Oligocene species have been described from the Sannoisian of the Tyrol, and a sixth from the Chattian of northern Bohemia. There are two Miocene species in Switzerland and two in Styria: a Pliocene species is described by Krasser from Brazil. A single small-leafed species of *Euphorbiophyllum* is of rare occurrence in the middle Wilcox.

The genus *Drypetes* Vahl. has about a dozen existing species confined to tropical and subtropical America. Three extend southward to northern Brazil and two range northward to the Florida keys. There are two well-marked species in the Wilcox flora—one an Eocene prototype of the existing *Drypetes keyensis* Urban, and the other of the existing *Drypetes lateriflora* (Swartz) Urban, both small trees of the coastal flora of southern peninsular Florida, the Bahamas, West Indies and Antilles. The genus, which has not previously been recorded in the fossil state, was probably of American origin and there is no evidence that it ever spread to the eastern hemisphere.

The order Sapindales, sometimes called the Celastrales, includes some twenty families, together containing about 3,200 species, the largest families in the order of their size being the Sapindaceæ which has more than twice as many species as any of the others; the Celastraceæ, Anacardiaceæ, Balsaminaceæ, and Ilicaceæ. As in the preceding order, the Sapindales start with isocarpic forms and pass to

those in which the carpels are reduced in number, and in the more evolved families the flowers have become zygomorphic. Since there are several distinct lines of development and the separation from the Geraniales is based on characters that seem trivial, it seems probable that the families comprising these two orders as at present understood represent a plexus of forms whose filiations are not yet understood.

The first family of the Sapindales that is represented in the Wilcox flora is the Anacardiaceæ, an exceedingly natural group. It contains about 58 existing genera and 435 species of shrubs and trees with round pithy branches, resinous and frequently toxic juice, alternate, simple, palmate or pinnate, exstipulate leaves, and drupaceous fruits with exalbuminous seeds. The Anacardiaceæ makes its greatest display in the tropics and subtropics of both hemispheres but in the existing flora is especially characteristic of the Malaysian region. *Rhus* is by far the largest genus and the only one of the family found in the extra tropical regions of both the northern and southern hemispheres. The present geographical distribution shows many anomalies throughout the family. Thus the genus *Camposperma* Thwaites has eight species in Madagascar, Ceylon, Sumatra, Borneo and the Malaccas and a single species in northern Brazil. The genus *Sorindeia* Thouars of tropical Africa and Madagascar is most closely allied to the genus *Mauria* Kunth of the Andes of South America. The genus *Calesium* Adanson has 13 species in tropical Africa and one in the East Indies. The Eurasian genus *Pistacia* Linné has a single species in Mexico. The genus *Thyrsodium* Bentham has 4 species in the Amazon region of South America and one in tropical West Africa. The subfamily Mangiferæ with about 80 species is entirely Malaysian except for a species of *Gluta* Linné in Madagascar and the genus *Anacardium* Linné which is confined to tropical South America, chiefly in Brazil. The subfamily Spondieæ is found in the tropics of all the continents, excepting Europe. The subfamily Rhoideæ is found on all the continents and shows a pairing of a considerable number of genera in equatorial Africa and America. The two remaining subfamilies, the Semecarpeæ and the Dobineeæ are restricted to the region extending from India to Australia. The

family contains twenty monotypic genera distributed as follows: Asia 5, Australia 3, Africa 6, Madagascar 3, North America 2, and South America 1.

The fossil records of the Anacardiaceæ are very incomplete although there seems to be no doubt that it was represented in both Europe and North America as far back as the Upper Cretaceous. As in the existing flora the most abundant genus in the fossil record is *Rhus* to which over one hundred species have been referred. Eight of these are Upper Cretaceous forms the oldest coming from North American strata correlated with the Cenomanian (Raritan, Dakota). The genus appears in Europe in the Turonian of Bohemia. There are over a dozen Eocene species of *Rhus,* widely scattered. Thus there are three in the Ypresian of Alum Bay, four in West Greenland and North American species in the Lance, Kenai, Ft. Union and Green River formations. The genus doubles its known species in the early Oligocene, being especially well represented in southern France, but also recorded from the Tyrol, the Baltic amber, Italy, Carniola and Styria.

In the Miocene *Rhus* seems to have been as abundant, as well differentiated, and as widely distributed as it is in the existing flora, for over sixty fossil species have already been described. The records embrace all European countries where Miocene plants have been found as well as Iceland and the following North American localities:—Maryland, Virginia, Colorado, Yellowstone Park, Idaho, Nevada, Oregon and California. Only a small number of Pliocene species are known and these are recorded in Spain, France, Italy, Germany and Slavonia.

Three Pleistocene species are recorded, 2 from Japan and one from China, all closely related to still existing species of that region. Engler[85] some years ago reviewed the geological records of *Rhus* and concluded that most of the then known fossil species belonged to the section Trichocarpæ (in the existing flora with over a score of species mostly confined to North America and eastern Asia), or the section Gerontogeæ (with 75 existing species mostly confined to South Africa). A few fossil forms he considered as representing the section Venenatæ, which has about 14 existing species in North

[85] Engler, A., *Bot. Jahrb.,* Bd. 1, 1881, pp. 413–419.

and South America. The other sections into which the genus is subdivided were not recognized among the fossil forms.

The allied genus *Cotinus* with two or three existing species in Eurasia and North America is probably represented by some of the fossil forms referred to *Rhus, e. g.*, Saporta considers *Rhus antilopum* Unger from the Aquitanian of Kumi as a species of *Cotinus*. This author has also described *Cotinus palæocotinus*, and Cockerell has described *Cotinus fraterna* from the Miocene of Florissant, Colorado.

The genus *Pistacia* with five existing Mediterannean species and one each in eastern Asia and Mexico has about fifteen known fossil species the oldest, of doubtful value, coming from the Raritan of Staten Island. A second Cretaceous species is found in the Laramie of Colorado. Europe enters the record with a Ypresian species from Alum Bay. There are three Oligocene species in France and seven Miocene species in France, Bohemia, Styria, Galicia, and Transylvania. There is a Pliocene species in Styria, an extinct Pleistocene species on the Island of Madeira, and the existing *Pistacia lentiscus* Linné in the Pleistocene of the Island of Santorin.

The genus *Anacardites* Saporta (*Anacardiophyllum*) has been used as a form-genus for fossil Anacardiaceæ of uncertain generic relationship. As used by Saporta it represented fossil forms resembling existing species of *Mangifera, Anaphrenium, Spondias, Comocladia, Holigarna,* etc., but not determinable with certainty. Heer has described a supposed species of *Anacardites* from the Atane beds of West Greenland. There are two species in the Sparnacian and one in the Ypresian of France and seven well marked species in the Wilcox. There are two or three Oligocene species in France and Germany and two or three Miocene species in France and Styria. Felix has described petrified wood from the Eocene of the Caucasus which he refers to *Anacardioxylon,* a type also represented in the Oligocene of Antigua in the American tropics (species compared with existing genus *Spondias*).

The floral genus *Heterocalyx* Saporta (*Trilobium* Saporta, *Elaphrium* Unger, *Getonia* Unger) which occurs at a number of horizons in the Oligocene of France, Croatia, and Styria is represented by a second species in the Wilcox. Saporta compared it with the South

American genus *Astronium* but Engler (op. cit.) considers it most like the Malayan genus *Parishia.*

The genus *Metopium,* not certainly recognized heretofore, has a well-marked species in the Wilcox. Several Tertiary woods are described by Unger as *Rhoidium* and Saporta has described a species of *Schinus* from the French Oligocene (Gargas) which is wrongly determined according to Schenk (p. 541).

The genus *Spondiæcarpum* has a species in the early Eocene of France and a second in the Aquitanian of Rhenish Prussia. Recently Fritel has described leaves from the Aquitanian of France which he calls *Semecarpites* that are very close to the existing genus *Semecarpus* which has about 40 species ranging from India to Australia.

The family Ilicaceæ (Aquifoliaceæ) is a relatively small one comprising only five genera and about 180 existing species. They are shrubs or trees with alternate, simple, entire or toothed, often coriaceous leaves. The flowers are small, dioecious and hypogynous. The fruit is a drupe with a thin fleshy sarcocarp enclosing as many crustaceous nutlets as there are carpels. The genus *Ilex* Linné to which all but seven of the existing species are referred is found in all tropical and temperate regions of the world except western North America, Australia, New Zealand and New Guinea. The remaining genera of the family are *Oncotheca* Baillon with a single species in New Caledonia, *Nemopanthes* Rafinesque with a single species in temperate North America, *Sphenostemon* Baillon with two species in New Caledonia, and *Byronia* Endlicher with three species, one in Tahiti, one in the Hawaiian Islands and one in Australia. This modern distribution is a certain indication that the family has an extended geologic history.

Over a hundred fossil species have been referred to the genus *Ilex.* At least thirteen species are recorded from the Upper Cretaceous. All but one from the Turonian of Bohemia are from the western hemisphere and include two in the Raritan formation, three in the Magothy formation, seven in the Dakota sandstone, one in the Atane and two in the Patoot beds of western Greenland.

There are about fourteen Eocene species including four in the Wilcox, one in the Ypresian of England, one in the Fort Union, four in the Green River beds, five in Greenland, one in Alaska and one in

Australia. There are over a score of Oligocene species including one from Chili that may even be of Eocene age. The lower Oligocene or Sannoisian has eleven species in France, Tyrol, Saxony and Prussia and includes three species of flowers described by Caspary from the Baltic amber. The Middle Oligocene or Tongrian has six species in France, Italy, Germany and Styria and there are seven species in the Upper Oligocene (Chattian) of France, Bohemia and Greece. Upwards of fifty species have been described from the Miocene of Europe and Asia, and from New Jersey, Colorado and California in this country. The most prolific Miocene area is that of France. About ten species are known from the Pliocene of Spain, France, Italy, Prussia and Asia Minor. One fossil and four recent species are found in the Pleistocene of Virginia, North Carolina, Alabama, Kentucky and the Island of Madeira. In addition to the fossil forms referred to *Ilex,* two Miocene species from Italy and Styria are referred to the genus *Nemopanthes* and four forms from the late Oligocene or the Miocene of Prussia, Styria, Croatia, Bohemia and Greece are referred to the genus *Prinos* Linné, which is usually considered a section of *Ilex*. The four species from the Wilcox that are referred to *Ilex* are represented in the collections by a small amount of mostly poor material and are without special significance.

The family Celastraceæ includes about 40 genera and upwards of 400 existing species of trees and shrubs with opposite or alternate, simple, persistent or deciduous leaves and capsular or drupaceous fruits. The three large genera *Euonymus, Celastrus* and *Gymnosporia* are practically cosmopolitan and several additional genera localized in the modern flora were cosmopolitan in the Tertiary.

The following 12 genera with over 100 species are confined to America: *Fraunhofera, Mortonia, Glossopetalum, Schaefferia, Goupia, Maytenus, Pachystima, Zinowiewia, Plenckia, Wimmeria, Gyminda, Rhacoma.* The genera *Glyptopetalum* and *Tripterygium* together with five species are confined to Asia. The genera *Hypsophila, Denhamia* and *Hedraianthera* together with seven species are confined to Australia. And the following ten genera with about 60 species are confined to Africa or Madagascar: *Putterlickia, Catha, Pterocelastrus, Polycardia, Ptelidium, Cassine, Elæodendron, Maurocenia, Schrebera* and *Lauridia.*

The family is definitely represented in the Cretaceous by at least five genera and is an important element in most Tertiary floras. The oldest known genus is the form-genus *Celastrophyllum* proposed by Gœppert. Five well-marked species occur in the Patapsco formation (Albian) of Virigina and Maryland. At the base of the Upper Cretaceous, particularly in North America, a large number of species occur. Upward of thirty have been described of which number two are recorded from New Zealand and two from the Cenomanian of Niederschœna in Saxony. There is a species in the Atane beds of Greenland and three in the Patoot beds. The remainder occur in the United States and have the following distribution: ten in the Raritan formation of New Jersey and Maryland, twelve in the Tuscaloosa formation of Alabama, two in the Magothy formation of New Jersey and Maryland, two in the Middendorf beds of South Carolina, seven in the Dakota sandstone, and two in the Black Creek formation of North Carolina. There are ten Eocene species—seven in the basal Eocene of Belgium, one in the Ypresian of England and two in the Claiborne group of the Mississippi embayment. There are five Miocene species in Italy, Bohemia and Styria; a Pliocene species in Italy; and four Tertiary species from the Island of Java. Another form-genus is *Celastrinites* Saporta which has four species in the Paleocene of France, one in the Denver formation of Colorado, another in the Livingston formation of Montana, and a seventh in the Miocene of Florissant, Colorado.

The genus *Celastrus* Linné is the largest fossil genus of the family and its history shows that while its present center of distribution is in the uplands of southeastern Asia and the East Indies the ancestral stock was cosmopolitan and very abundant in the Tertiary of America and Europe, with a strong probability that it originated in the former area at the dawn of the Upper Cretaceous or somewhat earlier. The oldest known species, *Celastrus arctica* Heer, is found in the Raritan and Magothy formations of New Jersey and Maryland and in the Patoot beds of Greenland. No less than thirty species of *Celastrus* have been described from the Eocene. These include six Ypresian species from England, five species in the Wilcox flora, one in the Denver, ten in the Fort Union, one in the Kenai of Alaška, three from Greenland and four from Australia.

There are also about thirty Oligocene species, all European, and including remains in the Baltic amber, in France, Switzerland, Germany, Austria-Hungary and Greece. There are at least a dozen species in the Chattian of Bohemia. Over fifty Miocene species have been described ranging throughout Europe, in eastern Asia, and in Virginia, Colorado, Idaho and Oregon in this country. About a dozen Pliocene species have been described from Spain, France, Italy and Sicily.

The genera *Cassine* Linné and *Pterocelastrus* Meissner both now confined to South Africa and Madagascar, each has a fossil species in the Miocene of Bohemia. The genus *Pachystima* Rafinesque, with two existing species in North America, has an Upper Cretaceous species in North Carolina and a Miocene species in Colorado.

The genus *Maytenus* Feuill, with about 70 existing species of the tropics and subtropics of South America has a well-marked species in the Wilcox flora. There are two species in the early Tertiary of Chili, one in the late Oligocene and three in the Miocene of southeastern Europe.

The monotypic genus *Gyminda* Sargent confined to Florida and the West Indies in the existing flora has a doubtfully determined fossil species in the Magothy formation of the Atlantic Costal Plain. The genus *Microtropis* Wall., with 9 or 10 existing species of the mountains of southeastern Asia from India to China and Japan, has a doubtfully determined form in the early Pliocene of Italy.

A well preserved flower in the Baltic amber is described by Conwentz as *Celastrinanthium Hauchecornei.*

The genus *Elæodendron* Jacquin, with about 25 existing species confined to South Africa, has a considerable geologic history. Four Upper Cretaceous species have been described—one from Australia, one from the Dakota sandstone, and two from the Magothy formation of the Atlantic coast. There are six Eocene species showing that the genus was represented in New Zealand (?), Australia (?), Alaska, the Ypresian of England and the Fort Union of the Rocky Mountain region. There are five Oligocene species in the Tyrol, Bohemia and Transylvania; nine Miocene species in France, Switzerland, Italy, Prussia, Bohemia and Styria; and four Pliocene species in Italy.

The remaining genus known in the fossil state, *Euonymus* Linné, has about sixty existing species widely distributed throughout the northern hemisphere but most numerous in the Asiatic tropics and in China and Japan. Upwards of thirty fossil species are known, being based upon both fruits and leaves. There are four well-marked Eocene species all of which are confined to North America where they are represented in West Greenland, in the Fort Union and Green River beds of the Rocky Mountain region, and in the Wilcox of the Mississippi embayment. The species of the latter region is a very abundant and characteristic form. There are four or five Oligocene species of *Euonymus* recorded from Bavaria, the Tyrol and Bohemia. The twelve Miocene species occur in France, Prussia, Bohemia, Styria, Croatia, and Hungary. There are four Pliocene species in Germany, Italy, and Slavonia; and two still existing species occur in the Pleistocene of France.

From this very brief survey of the fossil history of the Celastraceæ it is seen that there is a probability, similar to that shown by so many other families of Dicotyledonæ, that the ancestral stock originated in the western hemisphere.

The family Sapindaceæ consists of about 118 genera and over one thousand existing species of trees or shrubs with alternate, pinnate, exstipulate, persistent, or deciduous leaves and drupaceous or capsular fruits with crustaceous mostly solitary seeds. About one third of the genera are lianas. Most of the family is confined to tropical and subtropical regions and about 23 per cent. of the genera (27) and 34 per cent. of the species (345) are confined to America. There are more genera (30) confined to the African region but only about one fifth as many species (75).

The genera *Cardiospermum, Schmidelia* (*Allophylus*) and *Sapindus* are found in all tropical countries. The genus *Paullinia* with over 120 existing species while mostly American is present in Africa and Madagascar. The genus *Dodonæa* with over 40 species in Australia has one or two forms found in all tropical countries and a single species in the Hawaiian Islands and Madagascar. *Harpullia* is common to Asia, Africa and Australia. There are two genera with about fifteen species confined to Australia, four genera with 66 species ranging from Asia to Australia, 10 genera with 22 species

confined to the East Indies, two genera with 20 species confined to Polynesia and 6 genera with 35 species ranging from Malaysia or the East Indies to Australia. It is quite obvious from these few facts regarding the existing distribution that the family is an ancient one and that there has been an extensive evolution of both generic and specific types in relatively modern times in the American tropics on the one hand and in the Malaysian region on the other.

The fossil record while much less complete than might be wished includes at least 13 genera of which six are extinct, and about 160 species, by far the largest number being referred to the still existing genus *Sapindus* which appears well differentiated and widely distributed at the dawn of the Upper Cretaceous. There are about ten Upper Cretaceous species of which all but four occur in pre-Senonian strata. Thus there are two in the Perucer beds of Moravia and Bohemia, one at Niederschœna in Saxony—all Cenomanian. Two in the Atane and one in the Patoot beds of West Greenland. Two in the Dakota group; two in the Tuscaloosa formation of Alabama, one in the Middendorf beds of South Carolina, one in the Woodbine formation of Texas; two each in the Raritan and Magothy formations of the Middle Atlantic states, one in the Montana group and two in the Laramie. I have given this Upper Cretaceous distribution in some detail because of the special interest attached to the deployment of the Upper Cretaceous Dicotyledonæ. It should be noted that seven of these Upper Cretaceous forms are North American. There are over thirty Eocene species of *Sapindus* of which two thirds are North American. The genus is very abundantly represented in both individuals and species in the coastal floras of the Wilcox group from which I have described no less than 9 species. There are four species in the overlying Claiborne group. Species of *Sapindus* are equally common in the Rocky Mountain province in the Denver, Fort Union and Green River beds. There is an Eocene species in Greenland and one each in New Zealand, Australia, Tasmania and Chili. There are four undescribed species in the Ypresian of England and a fifth in beds of the same age in Hungary. There is an Upper Eocene species in France and a second in Oregon.

There are six or more Oligocene species well distributed in Eu-

rope to which continent their discovery has thus far been confined. There are over 30 Miocene species found throughout southern Europe, in eastern Asia, and in North America (Colorado, Oregon and Yellowstone Park). The eight or ten Pliocene species are confined to southern Europe.

In addition to the genus *Sapindus* there are several form-genera derived from the same root. Thus *Sapindophyllum* has been applied to two species from the Albian of Portugal (?). To it are also referred a Cenomanian and a Chattian species from Bohemia and a Tertiary species from Japan. The term *Sapindoides* has been used by Perkins for *Sapindus*-like fruits preserved in the early Tertiary lignites of Brandon, Vermont, from which eight species have been described. In some respects the most interesting genus is *Sapindopsis* Fontaine represented by three abundant and well preserved species in the Patapsco formation (Albian) of Maryland and Virginia one of which is also present in the Fuson formation of the Black Hills, and which I have shown[86] to be very probably ancestral forms of the genus *Matayba* Aublet (Cupanieæ) which has upwards of two score existing species in the tropical and subtropical regions of America. This well-marked type suggests the interesting question of how early in the Mesozoic the ancestors of many modern genera may have been present in equatorial America.

The genus *Paullinia* Linné which has about 122 existing species mostly confined to the American tropics but sparingly represented in Africa and Madagascar, has an Oligocene species in Prussia and two early Miocene species in southeastern France and Bohemia.

The genus *Thouinia* Poit, which in the modern flora has about 15 species confined to the West Indies and Mexico, is represented by an early Tertiary, probably Eocene species, in Chili. The genus *Nephelium* Linné with over a score of existing species in southeastern Asia is recorded by Unger from the Aquitanian of Greece and by Geyler from the Tertiary of Borneo.

The genus *Kœlreuteria* Laxm. is represented by two Chinese species in the existing flora. In the fossil state it is recorded from the Tertiary of the Island of Sachalin, from Spitzbergen and from

[86] Berry, Md. Geol. Surv., Lower Cretaceous, pp. 467–474, Pl. 83–88, 1911.

Switzerland and Baden. Felix has described a genus, *Schmideliopsis,* based on fossil wood from the Oligocene of the Island of Antigua, very close to the existing genus *Schmidelia* Linné which has upwards of a hundred existing species in all tropical countries.

The modern Cupanieæ are represented in paleobotanical literature not only by *Cupania* but by species of *Cupanites* and *Cupanoides.* The latter generic term was proposed by Bowerbank for cupaniaceous fruits and seeds of which he described several characteristic species from the Ypresian of the Island of Sheppey. Similar forms have also been recognized in the Miocene of Carniola and in the Pliocene of Italy. The genus *Cupania* Linné has about 35 existing species confined to the American tropics. Several Ypresian species from the south of England have been referred to it by Ettingshausen and it has also been recorded from the Miocene of the Island of Sachalin. The greater number of *Cupania*-like forms have, however, been referred to the genus *Cupanites* Schimper. Nine or ten species have been described and with the exception of extremely doubtful forms from the Upper Cretaceous of New Zealand and the Eocene of Australia, the oldest authentic occurrences are the two species of the Wilcox flora. There is a third species in the overlying Claiborne group of the Mississippi embayment. The oldest European form is one from the late Oligocene of Styria. In the Miocene, species are recorded from Germany, Bohemia, Austria, Croatia and Hungary.

The genus *Dodonæa* Linné often made the type of a distinct family, the Dodonæaceæ, has about fifty existing species of which four fifths are Australian. *Dodonæa viscosa* Linné is cosmopolitan in the tropics and there are one or two additional species in the American tropics as well as one in the Hawaiian Islands and another in Madagascar. The genus (including *Dodonæites*) was evidently widespread in former times and upwards of a score of fossil species, based on both leaves and fruits, have been described. The oldest known forms are two species in the Ypresian of the north of England and the two contemporaneous species in the Wilcox, which are represented by both leaves and characteristic fruits. There are five Oligocene species in France, Tyrol, Bohemia and Styria; and ten

Miocene species in Prussia, Baden, Switzerland, Bohemia and Croatia. A well-marked species occurs in the Claiborne (Lutetian) ranging along the Claiborne coast from northeastern Georgia to central Louisiana.

It is impossible from the known facts to discuss the place of origin of the family, but it is obvious that certain genera were evolved toward the close of the Lower Cretaceous in equatorial America and have inhabited that or adjacent areas throughout the long stretch of time down to the present.

The order Rhamnales includes about 1,000 existing species of shrubs, trees and vines about equally divided between the families Rhamnaceæ and Vitaceæ. It closely parallels the Sapindales in its floral development but is distinguished by the mostly tetracyclic flowers with opposite stamens and often lacking a corolla. The leaves are simple and typically alternate. Of the two families only the Rhamnaceæ is represented in the Wilcox flora.

The family Rhamnaceæ (Frangulaceæ) includes 47 genera and about 500 species of shrubs and trees mostly of the tropics but with several genera extending for considerable distances into the temperate zone, the genus *Rhamnus* in particular being mostly extratropical in the northern hemisphere. The genera *Zizyphus, Adelia* and *Gouania* are found in all tropical countries. Almost half of the genera are common to more than one continental area. America has the greatest number of peculiar genera (15) with about 85 species. Two monotypic genera are confined to Asia, five genera including the large genus *Phylica* Linné together with about 70 species are confined to Africa and five genera including the two large genera *Spyridium* Fenzl. and *Cryptandra* Smith in all with about 70 species are confined to Australia.

Ten or eleven genera, of which five are present in the Wilcox flora, are found fossil, the three largest being *Rhamnus, Paliurus* and *Zizyphus*. The genus *Rhamnus* Linné which is cosmopolitan in the northern warm temperate and subtropical zones has about seventy existing species. There are considerably over one hundred fossil species, mostly well characterized with simple often entire leaves with ascending secondaries and closely spaced fine percurrent

nervilles. There are a dozen or more species described from the Upper Cretaceous, the genus appearing in the Cenomanian in both Europe (Niederschœna, Saxony) and America (Raritan formation). There are six species in the Dakota sandstone, two in the Magothy formation, one in the Atane and two in the Patoot beds of Greenland. The genus is represented in the Montana group and the Laramie formation of the Western Interior and in the Senonian of Westphalia. There are about thirty Eocene species, the majority being North American. Species of *Rhamnus* are very common in the Raton and Denver formations along the Front Range of the Rocky Mountains and from the base to the top of the Wilcox. There are four species in the Raton, eight in the Denver and six in the Wilcox. The genus is also well represented in the later Eocene along the Pacific coast and in western Greenland. In Europe only a single species is recorded from the Paleocene. The Ypresian which is synchronoús with the Wilcox has three species in the south of England.

There are eleven or twelve Oligocene species in France, Prussia, Tyrol, Italy, Dalmatia, Styria, and Greece and a single undescribed species in the Apalachicola group of Florida. There are over two score Miocene species, *Rhamnus* being especially abundant in the Miocene of Switzerland, Italy, Bohemia, Prussia and Styria. It is also present at this time in Iceland, Spitzbergen, Manchuria and Sachalin Island. In this country there are species in British Columbia and in Colorado.

There are about thirteen Pliocene species, no less than nine being recorded from Italy and there is one known from the Island of Java. There is an extinct species in the Pleistocene of Hungary and a recent species in the Pleistocene of the Island of Madeira. In addition to the species referred to *Rhamnus* the form-genus *Rhamnites* Forbes founded on three species from the Eocene of the Isle of Mull has two American Upper Cretaceous species found in the Raritan, Tuscaloosa, Magothy and Dakota formations. There is a species in the Fort Union and another in the Wilcox. The genus *Rhamnacinium* of Felix is based on petrified wood. It contains five or six species found in the Eocene of the Caucasus, Texas, Saskatchewan and the Miocene of Yellowstone Park.

The genus *Paliurus* Jussieu with only two existing species ranging from southern Europe through southern Asia to China and Japan was cosmopolitan in former times. Upwards of 40 fossil species have been described. At least twelve are known from the Upper Cretaceous, all confined to the North American region. There are two each in the Raritan, Magothy and Laramie, five in the Dakota and one each in the Eutaw formation of Georgia, in West Greenland and Vancouver Island. There are ten Eocene species also confined to North America. Two of these are found in the Fort Union and there are three each in the Denver, in western Greenland and in the Wilcox. The leaves are not common in the Wilcox but the characteristic peltate fruits are not uncommon. The oldest European forms are two species in the Oligocene of France and there is a well marked species in the Oligocene (Vicksburg group) of Louisiana. The thirteen Miocene species are found in Asia (Siberia, Sachalin), Europe (Switzerland, Baden, Germany, Bohemia, Italy, Styria and France), and North America (Colorado and Oregon). The presence of numerous species of *Paliurus* in the Upper Cretaceous and Eocene of North America and their absence on other continents before the Oligocene renders it very probable that the genus originated in the western hemisphere.

The genus *Zizyphus* Jussieu with about forty existing species largely shrubs, often prostrate or scrambling, and rarely small trees, is mostly Indo-Malayan in its distribution but is represented by a few species in the tropics of eastern Asia, America, Africa and Australia. There are over fifty known fossil species and as in the genus *Paliurus* the ten Upper Cretaceous species are confined to North America. They are found in the Raritan and Magothy formations of New Jersey and Maryland, the Eutaw formation in Georgia, the Tuscaloosa formation in Alabama, the Woodbine formation in Texas, the Dakota sandstone of the West, the Patoot beds of Greenland and the Upper Cretaceous of Alaska. There are about twenty Eocene species including the two common and characteristic species of the Wilcox and one in the overlying Claiborne of the embayment region, five in the Denver, three in the Fort Union, two in the Green River, one in Alaska and one in West Greenland. There are two

Paleocene species in France and Belgium, four Ypresian species in the south of England and a Lutetian species in France. There are eight Oligocene species very common in deposits of this age throughout Europe. Over twenty species have been recorded from the Miocene of Colorado and California in this country, from France, Switzerland, Germany, Italy, Austria-Hungary, and Russia in Europe, and from Japan and Java in Asia. There are three or four Pliocene species in Europe. While the evidence is not so clear as in the case of *Paliurus* there is a possibility that *Zizyphus* too is of occidental origin.

The genus *Reynosia* Grisebach with only two existing coastal species ranging from the Florida keys through the West Indies has two characteristic species based on leaves in the Wilcox flora and a third species based on the petrified wood in the overlying Claiborne deposits of Texas.

The genus *Berchemia* Neck. has about a dozen existing species, ten of which are confined to eastern and southeasern Asia. There is one in eastern extratropical North America and one in eastern Africa. This distribution could not have been brought about except by the agency of a cosmopolitan Tertiary range. While the specific differentiation of *Berchemia* is limited to five or six fossil forms these are very common and wide ranging. The earliest occurrences are North American and include the Raton, Denver and Fort Union formations of the Rocky Mountain province. The genus makes its apearance in Europe during the Oligocene and is common throughout that region in the Miocene, becoming restricted to southern Europe (France, Italy, Sicily and Slavonia) during the Pliocene.

A species of *Hoveniphyllum* supposed to represent the existing genus *Hovenia* Thunberg with a single existing species in southeastern Asia, is present in the Plio-Pleistocene of Japan. The genus *Colubrina* Brongniart with 15 existing species in tropical America and one in southeastern Asia is recorded from the Miocene of Bohemia.

The genus *Pomaderris* Labill with about 24 existing species confined to Australia and New Zealand has two species in the Eocene of the former region and three species (*Pomaderrites* Ettingshausen) in the Miocene of Prussia, Bohemia and Styria.

The genus *Ceanothus* Linné with about forty existing species confined to North America has included numerous fossil species subsequently referred to *Paliurus* or *Zizyphus*. There are four recorded from the Upper Cretaceous of Greenland, New Jersey, Vancouver Island and Westphalia; two Eocene species recorded from Greenland and British Columbia; a Miocene species in Prussia, Switzerland and Italy; and a Pleistocene species in Kentucky.

The next order, the Malvales, includes nine families and about 1,800 existing species. The Tiliaceæ, Sterculiaceæ and Bombacaceæ are the only ones represented in the Wilcox flora. The largest modern family, the Malvaceæ with over 800 species, many of which are herbaceous and range from 65° North latitude (Russia) to 45° South latitude (New Zealand), is not represented in the Wilcox. The order displays somewhat uneven or but little understood phylogenetic characters but is evidently allied to the succeeding order, the Parietales, through the family Elæocarpaceæ. These inequalities of evolution are shown among other ways by the complete syncarpy in the Tiliaceæ associated with an indefinite number of stamens and by the complex arrangement of the stamens in the Sterculiaceæ, associated with more or less incomplete union of the carpels. Both the leaves, flowers and fruits exhibit a wide range of variation throughout the order.

The family Tiliaceæ, represented in the Wilcox flora by a single, not very common form of *Grewiopsis*, has about 35 genera and 370 existing species mostly of tropical lands and showing two centers of differentiation and distribution—one surrounding the Indian Ocean and the other in northern South America. The geological history is confined to the four genera *Tilia* (or *Tiliæphyllum*), *Grewia*, *Grewiopsis* and *Apeibopsis*.[37] The genus *Tilia* Linné with 18 or 20 widely distributed existing species in the north temperate zone (absent in western North America and central Asia) has furnished about 25 fossil species based upon both leaves and fruits, the oldest known being from the North American Eocene. There are no conclusive Oligocene records except two French species, but about fifteen Mio-

[37] The genus *Luhea* has been described from the Eocene of Sézanne (Langeron) and from the Oligocene of Ménat (Laurent), both French localities.

cene species are found in North America, Europe, Asia and the Arctic regions. There are five Pliocene species recorded from Europe and Japan and six Pleistocene species in Ontario, New Jersey, France, Germany, Holland and Denmark. The genus has apparently had its existing range since Miocene time.

The genus *Grewia* Linné has about 90 existing species ranging from Arabia to China and Japan and through Malaysia to Australia, and from Abyssinia to South Africa. About fifteen fossil forms have been described, the oldest known, five Eocene species, coming from western North America. There are two Oligocene species in Europe and about six Miocene species in Oregon, Spitzbergen and throughout Europe. The larger number of *Grewia*-like fossil forms are, however, referred to the genus *Grewiopsis* of Saporta. Six of these are from the Upper Cretaceous and all are confined to North America, a very significant fact since several of them are especially well marked. They are found in the Magothy formation of the east coast, the Tuscaloosa formation of the south coast, and the Dakota Montana and Laramie formations of the western interior. There are about six Eocene species in the Denver, Lance and Fort Union: one in the Wilcox and one in the Claiborne of the Mississippi embayment region, six in the Paleocene of France and one in the Ypresian of England. There is also a Miocene (?) species recorded from Yellowstone Park. While it is quite possible that some of the fossil records ascribed to the genus *Populus* are those of *Grewia* or its ancestral stock, it seems clear that the latter genus or its immediate ancestors were common in the Upper Cretaceous and Eocene of North America.

The fourth fossil genus of Tiliaceæ is *Apeiobopsis* Heer[38] named from its affinity with the existing genus *Apeiba* Aublet which has five or six species confined to tropical South America. *Apeibopsis* includes not only leaves but very characteristic fruits. To it are referred somewhat doubtfully determined leaves from the Upper Cretaceous Dakota sandstone and Atane beds. There are about fourteen Tertiary species including a basal Eocene form from Wyoming, two Ypresian forms from England, a species from West Greenland

[38] To it should probably be referred the Arctic forms described by Heer as *Nordenskioldia*.

three species in the lignites of Brandon, Vermont, two Oligocene species from Italy and five Miocene species from France, Switzerland and Bohemia.

The family Bombacaceæ[39] with 20 genera and about 120 existing species is confined to the tropics and principally to the American tropics. The only known fossil forms are those of the genus *Bombax* or the allied *Bombaciphyllum* and *Bombacites*. *Bombax* Linné has about fifty existing species, all large tropical trees, and almost confined to America. There is a single species in Africa, about six in southern Asia and one in Austalia. The fossil species number over twenty, the oldest known[40] being a common form in the Perucer beds (Cenomanian) of Bohemia and Moravia. There are three species in the Ypresian of southern England and two well-marked forms in the Wilcox flora. There are five additional Eocene forms of which three are from Chili and two from eastern Australia. There are five Oligocene species recorded from France, Saxony, Bohemia and Carniola. The genus is represented in the early Oligocene (Sannoisian) of southeastern France not only by the foliage but by beautifully preserved flowers so that there is little ground for questioning the correctness of the identifications. There are five Miocene species in Bohemia, Croatia and Styria.

The family Sterculiaceæ includes about 5 genera and 800 existing species of mostly tropical shrubs and trees with prevailingly large, simple or digitately lobed or divided leaves; the flowers are sometimes apetalous and differ from those of the Malvaceæ in their 2-celled extrorse anthers. Syncarpy is more or less complete.

The Sterculiaceæ of the existing flora are found on all the continents except Europe. The genera *Sterculia, Helicteres, Melochia, Buettneria* and *Hermannia* have species in both the eastern and western hemispheres. The geologic history of the family extends back to the base of the Upper Cretaceous but is confined to a relatively few number of genera. The most abundant of these is the genus *Sterculia* Linné, which in the existing flora has about one

[39] Ettingshausen, "Ueber die Nervation der Bombaceeen," *Densk. k. Akad. Wiss. Wien. Math. Nat. Cl.*, Band 14, 1858, pp. 49–62, Pl. I.–XI.

[40] An Albian species of Bombax described by Fontaine is entirely valueless.

hundred species of large leafed trees. They are divided into three tribes named from the habit of the leaves the Digitatæ, Lobatæ and Integrifoliæ. The first of these range from farther India to Australia with only one or two American species. The second is most abundant in the American tropics but is also found in Asia and Africa and shows many parallelisms between the American and Asiatic forms. It is most abundantly represented in the past history of the genus. The third and largest modern tribe, the Integrifoliæ, has five or six American species and the balance are found in Asia and Africa.

The fossil forms (sometimes referred to *Sterculiphyllum*) number more than fifty species. Upwards of a score are known from the Upper Cretaceous. These are mostly American and are referable to the tribe Lobatæ which may well have originated in the western hemisphere. There is a species each in the Credneria sandstone of Saxony and the Perucer beds of Bohemia (both Cenomanian) and a third in the Turonian of the latter country. The balance are North American and include species in the Raritan formation, the Cheyenne sandstone of southern Kansas, and in British Columbia, a species in the Patoot beds of West Greenland and six species in the Magothy formation of the Atlantic Coastal Plain and eight species in the Dakota sandstone of the western interior. There are less than a dozen Eocene species, the majority being confined to the lower Eocene. Thus there are three species in the Paleocene of France and another in the Ypresian of England as well as one or two in the Denver and Raton formations of the Rocky Mountain front range. The single large Wilcox species is entirely typical and shows the usual variability in lobation and size. It appears to be filiated with *Sterculia Snowii* Lesquereux from the American Upper Cretaceous, and may be exactly matched by several existing species. There is a small leafed species in the middle Eocene (Claiborne group) of the embayment which exactly matches the typical *Sterculia labrusca* Unger from the European Tertiary and the existing *Sterculia diversifolia* Don. It is closely parallelled by two American Upper Cretaceous species—*S. minima* Berry and *S. mucronata* Lesquereux. There are upward of ten Oligocene species widely scattered over Europe and about 15 Miocene species, mostly

European, with a single species on the east coast of Asia (Sachalin) and two species in Colorado, one of them especially well marked. There are several Pliocene species in southern Europe.

Two somewhat different species of sterculiaceous capsular fruits from the Wilcox are referred to a new genus, *Sterculiocarpus*. The larger of these, *S. eocenicus,* seems referable to the subfamily Buettnerieæ, while the smaller, *S. sezannelloides,* is referable to the Lasiopetaleæ or Helictereæ. Both are very similar to the fruits from the Paleocene of Sézanne referred to the genus *Sezannella*. The latter genus with two species was described by Viguier from casts of wonderfully preserved flowers as well as fruits from the celebrated Travertins of Sézanne and referred with great certainty to the Lasiopetaleæ.

The tribe Dombeyeæ with seven genera and about 75 existing species is almost entirely confined to Africa and the adjoining islands, five or six species of the genus *Melhania* Forsk, only, ranging from Arabia to farther India. This tribe is represented in fossil floras by the genus *Dombeyopsis* Unger named from its supposed affinity with the modern genus *Dombeya* Cav. which has 40 African, mostly Madagascar, species. About 30 species have been referred to *Dombeyopsis*. They are liable to be confused with *Luhea, Grewia* and other forms of the allied family Tiliaceæ. There are three species in the Laramie Cretaceous, two in the Denver formation, twelve (according to Massalongo) in the Upper Eocene of Monte Bolca in Italy, five in the European Oligocene and six in the Miocene of Iceland, France, Switzerland, Prussia, Silesia and Styria. A Pliocene species is recorded from central France. Fossil wood described as *Dombeyoxylon* is recorded by Schenk from the late Tertiary near Cairo, Egypt.

The Buettnerieæ are represented by a doubtful species described from the Miocene of Colorado, and probably by some of the fossil forms referred to other genera, *e. g.,* some of the palmately veined *Ficus*-like forms such as *Ficus occidentalis* and *Ficus Schimperi* both of which are present in the Wilcox flora. Flowers of *Buettneria* were reported from Sézanne by Solms-Laubach but this probably refers to the subsequently described genus *Sezannella,* mentioned in a preceding paragraph.

The Helictereæ are represented by a doubtful species of *Helicteres* Linné described from the Pliocene of Italy and by forms referred to the existing genus *Pterospermum* Schreb. or to the extinct genus *Pterospermites* Heer. Over 30 species have been described. There are nine or ten in the Upper Cretaceous all of which are North American, and their combined range extends from New York to western Alabama, throughout the Rocky Mountain and Great Plains province and in the Atane beds of Greenland. There are about a dozen Eocene species all North American except a single species in the Paleocene of France. The American forms extend northward to West Greenland and Alaska. There are two or three species in the European Oligocene and ten Miocene species throughout Europe and in western North America (Yellowstone Park, California, mouth of the Mackenzie River). A single Pliocene species is recorded from France. It seems probable that this type originated in the western hemisphere since it is so abundantly represented in that region during the Upper Cretaceous and Eocene. The modern species of *Pterospermum* are, however, confined to eastern tropical Asia.

The order Parietales includes thirty families together with over four thousand existing species, the largest families being the Guttiferæ (775), Flacourtiaceæ (530), Begoniaceæ (425), Violaceæ (400) and Dipterocarpaceæ (330). None of these families are present in the Wilcox flora, where the order is represented by the two families, the Dilleniaceæ and Ternstrœmaceæ. The Parietales are prevailingly syncarpous and show affinities with the Ranalian plexus through the Dilleniaceæ which were formerly referred to that order. The alliance as a whole is a complex one including several divergent lines of development with, on the whole, a gradual increase in floral complexity.

The family Dilleniaceæ contains 14 genera and about 275 existing species found on all the continents, the genus *Tetracera* being cosmopolitan in the tropics. The genera *Empedoclea, Curatella, Doliocarpus* and *Davilla* together with 50 species are confined to the American tropics: *Hibbertia* and *Pachynema* together with 75 species are Australian, there are five genera with about 25 species confined to the Asiatic tropics; the genus *Saurauia* (or *Saurauja*),

with about 60 species, is common to Asia and South America; and the genus *Dillenia* with about 25 species ranges from Asia to Australia; so that on the whole the family is prevailingly oriental in the existing flora.

The fossil record is unfortunately most incomplete, illustrating however a wider range of the genera in the past in response to milder climatic conditions in both the north and the south temperate zones during the Tertiary, and also the fact that several of the modern American genera have been American throughout their known geologic history. Thus *Empedoclea* with two existing South American species, sometimes made a subgenus of *Tetracera*, has a fossil form in the eary Tertiary of Chili. The genus *Doliocarpus* with about 20 recent species also in the South American tropics has two fossil forms in the early Tertiary of Chili. The genus *Davilla* with 25 modern species in tropical America is doubtfully represented in the Wilcox flora by *Calycites davillaformis* Berry.

The genus *Saurauja* with 60 modern species in South America and Asia has a species in the Paleocene of France, another in the Ypresian of the south of England and a third in the Miocene of Croatia.

The genus *Dillenia* with 25 existing species confined to Asia and Australia is represented by a form in the Paleocene of Belgium and by some of the Wilcox species referred to the form-genus *Dillenites*. The genus *Tetracera* with 40 recent species found in all tropical lands, has two fossil species in the early Tertiary of Chili, another in the Pliocene of Java and is represented in the Wilcox flora by some of the species of *Dillenites*. I have recognized five well-marked species of *Dillenites* in the Wilcox and these appear to represent modern forms of both *Dillenia* and *Tetracera*.

Conwenz described three species of *Hibbertia*, a large Australian genus, in the Baltic amber (Sannoisian) but Schenk considered that they did not belong to either this genus or even the family.

The family Ternstroemaceæ (Theaceæ) contains about 16 genera and 175 existing species mostly tropical but extending into the north temperate zone in North America and eastern Asia (*Thea, Gordonia* and *Stewartia*). The following seven out of the sixteen genera are confined to a single area: *Bennetia* Martius with five species inhabits

the South American strand, *Asteropeia* Dub. is confined to Madagascar, *Thea* Linné with sixteen species is confined to southern and eastern Asia, *Mountnorrisia* Szysz. with two species is a native of the East Indies, the three monotypic genera *Visnea* Linné, *Tremanthera* Müller and *Pelliciera* Tr. and Planch. are confined respectively to the Canary Islands, New Guinea and Central America. The remaining nine genera, all relatively small, are all found in more than one region. Thus *Archytæa* Martius has two species in northern South America and a third in the East Indies; *Gordonia* Ell. has two North American species and fourteen scattered from India to Malaysia; *Hæmocharis* Salisb. has nine American and five Asian species; *Stewartia* Linné with five species is found in North America and Japan; *Taonabo* Aublet has 20 species in South America and eight in Asia; *Adinandra* Jack. has 19 African species and one in Asia; *Eurya* Thunb. with 36 species and many varieties is confined to tropical America and the East Indies.

This remarkable existing distribution and the pairing of America and Asia as well as the fact that it requires five subfamilies for the reception of only sixteen genera are sure indications that the family has an extended geologic history and that many of the genera were once cosmopolitan. Unfortunately most of this history is unknown.

The genus *Stewartia* is represented in the Baltic amber by a fine flower (*Stewartia kowalowskii* Caspary) and by leaf remains from the Plio-Pleistocene of Japan (Mogi). *Gordonia* has a species in the Pleistocene of Java. The genus *Eurya* Thunberg, now American and East Indian, has a species in the Oligocene of France (*Freziera* Swartz). Fossil wood described by Felix and named *Ternstrœmiacinium* occurs in the Eocene of the Caucasus. *Visnea* Linné, now confined to the Canaries, has a typical fruit in the Aquitanian of Rhenish Prussia. The genus *Ternstrœmia* Nuttall (antedated by *Taonabo* Aublet) has several fossil species, the oldest (*Ternstrœmiphyllum*) coming from the Perucer beds (Cenomanian) of Bohemia. It has two species in the Ypresian of the Isle of Wight, one in the Miocene of Bohemia and another in the Miocene of Croatia. I have described four well-marked species of *Ternstrœmites* from the Wilcox group and similar forms are present in the overlying Claiborne group (Lutetian). Finally the very abundant species in

the North American Cretaceous described as *Celastrophyllum* and already referred to in the discussion of the Celastraceæ are very probably, in part at least, referable to this family, so that enough is known of the geologic history of the group to confirm at least the statement made in a preceding paragraph that it must have had a long and extended history.

The family Lauraceæ with in the neighborhood of 1,000 existing species distributed among forty to fifty genera is often placed next to the family Anonaceæ among the Ranales (*e. g.*, in Engler and Prantl's "Naturlichen Pflanzenfamilien"). It may be noted, however, that the spiral arrangement of floral organs characteristic of the order Ranales is replaced by a cyclic ararngement and hypogny is also replaced by epigyny, so that I follow various students in referring the Lauraceæ to the order Thymeleales, the other large family of which, the Thymelæaceæ (not known in Wilcox flora), has about 400 existing species, chiefly of temperate Australia and the Cape region of Africa.

The geographical distribution of the Lauraceæ cannot be disposed of in a similar simple statement since there are not only many anomalies in the distribution of the existing species but we know so considerable a part of the geologic history that our difficulties seem increased thereby rather than diminished. For example the existing species of the family are divided into eight tribes, no one of which except the monotypic Eusideroxyleæ of Borneo is restricted to a single continental region.

The largest of these tribes is the Cinnamomeæ with upwards of 500 species endemic on all the continents but Europe, and chiefly Asiatic and American. The four genera *Persea, Phœbe, Notaphœbe* and *Mespilodaphne* are found in both hemispheres; *Cinnamomum* and *Machilus* are oriental; while *Oreodaphne, Strychnodaphne, Nectandra, Pleurothrium, Umbellularia, Dicypellium* and *Synandrodaphne* are occidental; the first three being large genera and the last four being monotypic.

The tribe Litseæ, with six genera and about 200 species, is represented on all the continents except Europe and Africa. Only 9 of these two hundred species are found in the occident and yet among these is the monotypic North American genus *Sassafras,* and

the genus *Sassafridium* confined to the American tropics. All of the other genera are found on more than one continent.

The tribes Apollonieæ, Cryptocaryeæ and Cassytheæ are found on all the continents but Europe. The Laureæ are Eurasiatic and the Acrodiclidieæ are confined to Central and South America, except the genus *Endiandra* which with 16 species occurs in the East Indies and Australia.

The problem of correctly identifying leaves of the various genera of this family is beset with almost unsurmountable difficulties, not the least of which is due to the wide differences in usage among students of the recent forms where the whole plant is available for study. Long-continued paleobotanical practice has been to refer most fossil leaves that lacked the more apparent characters of *Cinnamomum* or *Sassafras, Persea* or *Malapœnna,* etc., to the comprehensive genus *Laurus* given at a time when *Laurus* was used in a comprehensive sense, and sometimes still more generalized by paleobotanists as *Laurophyllum* for lauraceous leaves of uncertain generic affinity and not necessarily close to the existing species of *Laurus,* in fact they are in general not true species of *Laurus.* I have departed from this practise of describing new species of *Laurus* for a variety of reasons foremost among which is the very great affinities between the Wilcox flora and the existing flora of the American tropics, the evidence from the foliage of a large number of genera being coroborated by fruits or seeds or wood anatomy. I have used this similarity with a great deal, perhaps too much, confidence and the result has been that the following stand out as the more important lauraceous types in the Wilcox flora:

Nearly all are seemingly members of the subfamily Persoideæ and under this subfamily of the tribe Cinnamomeæ as segregated in Engler and Prantl's "Naturlichen Pflanzenfamilien."

First the genus *Cinnamomum,* usually readily recognized and certainly represented in our Eocene floras.

Second the genus *Persea,* represented by the larger and wider forms with the typical venation of this genus.

Third the genus *Nectandra,* so abundant and characteristic of the existing flora of tropical and subtropical America, represented by several species very close to modern forms.

Fourth, I have failed to follow the latest usage in recognizing the genus *Ocotea* as such, since for obvious reasons it seems better to recognize the genera *Mespilodaphne* and *Oreodaphne* of Nees rather than to regard them as subgenera of *Ocotea*. The third subgenus of *Ocotea*,—*Strychnodaphne*, I have failed to recognize in the Eocene flora of this area.

The only apparent oddity in distribution shown by the Wilcox Lauraceæ in comparison with recent floras of tropical America is the abundance of *Cinnamomum*, and this simply adds confirmation to the well-known fact of the cosmopolitanism of this genus in the early Tertiary. Grisebach records only 28 species of Lauraceae in his flora of the British West Indies. Most of these are not coastal forms although many have a wide range from lowlands to mountains. As regards the Lauraceæ those of the Wilcox, which number 30 different forms, are more closely comparable with the more abundant modern representation of this family in northern South America. This receives more or less confirmation from a study of the balance of the Wilcox flora. It would seem from a consideration of all of the facts that the early Eocene floras of the Mississippi embayment are much more like those existing at the present time along the Caribbean sea in Central America and northern South America than they are like those of the West Indies. I do not mean by this that the Wilcox flora has not many points of resemblance to the lowland flora of the West Indies and that of the Florida keys. They contain very many common types, but with the following difference. The Mississippi embayment Eocene floras represent a maximum northward extension of a flora like that which now inhabits northern South America. At the end of the Oligocene with the southward migration of the temperate Miocene fauna as far as Florida, this flora retired to the South American mainland and the present flora of the West Indies, Florida keys, Bahamas and Bermuda represent a later northward migration from that area, a migration in which some of the Wilcox types were left behind.

The existing species of *Cinnamomum*[41] number about fifty. They are confined to the Oriental tropics except for their extension into the warmer more humid part of the temperate zone in Japan, and

[41] Staub, "Die Geschichte des genus Cinnamomum," Budapest, 1905.

they have their chief center of differentiation in the elevated region of Burma, Siam, Cochin-China and Malaysia, although they are cultivated in all tropical countries and outside the tropics in Europe, Africa and North America. Their fruits are eaten by birds which seed them freely so that they commonly escape from cultivation. Thus *Cinnamomum Camphora* (Linné) Nees and Eberm. is naturalized throughout peninsular Florida, and the commercial *Cinnamomum zeylanicum* Breyn., is readily naturalized in the same manner from the Oriental camphor plantations.

While the data for constructing the geologic history of *Cinnamomum* are far from complete there are more known fossil than recent species and these show, as in the case with so many plant groups, surprising extensions of range during the Upper Cretaceous and Tertiary. The original home of the genus is unknown for it appears in the early part of the Upper Cretaceous at about the same time in New Zealand, Australia, central Europe, Greenland, North and South America. The European and North American records appear to be slightly older than the balance and would indicate that the Asiatic region may have been the original home of the genus which spread northeastward across the Behring region to America and northwestward into the European region, the latter largely an archipelago at that time.

The Eocene records include all of the continents except Antarctica and South America. The Oligocene records are chiefly European and African, although the genus is still represented in the Florida Oligocene. During the Miocene *Cinnamomum* was abundant in Europe and present in Asia but appears to have become extinct in North America, at least there are no conclusive North American records. A number of fruits from the Brandon (Vermont) lignites have been referred to *Cinnamomum* but these lignites are in my opinion pre-Miocene in age. The Pliocene records are entirely European and East Indian. The genus appears to have lingered as a common type in Mediterranean Europe until the changing climates that ushered in the Pleistocene glaciation caused its extinction, any connected distribution with its present Oriental home across southwestern Asia having already been interrupted by the orogenic movements and the development of arid conditions in southwest Asia.

There are six well-marked types of *Cinnamomum* leaves described from the Wilcox group, some of them being abundant and generally distributed, and all but two appear to be new to science. In addition buds and flowers that suggest this genus are described under the form-genus *Laurophyllum.*

There are two species of *Persea* in the Wilcox flora. Disregarding the fossil forms referred to *Laurus* in a comprehensive sense there are about fifty known fossil species of *Persea* which is about the number of the existing species. All six of the Upper Cretaceous forms are American where they are widely distributed. By Eocene times they had reached Europe and South America and they are cosmopolitan in the northern hemisphere throughout the Tertiary, being especially abundant in the Pliocene of the Mediterranean region. It would seem as if their Cretaceous origin was occidental, that they spread over the northern hemisphere during the Tertiary and became restricted to southeastern Asia, the Canary Islands and America during the Pleistocene.

The genus *Ocotea* of Aublet with over 200 existing species is, it seems to me, composite, and I regard Nee's three genera *Mespilodaphne, Oreodaphne* and *Strychnodaphne* as distinct. The modern species of *Mespilodaphne* are confined to South Africa and tropical America. The fossil record is almost entirely merged in the forms referred to *Laurus.* I have recognized four well-marked species in the Wilcox flora. They are abundant types and some range from the base to the top of the deposits, and along the Wilcox coast from Mississippi around the head of the embayment and westward to western Texas.

The genus *Oreodaphne* has been recognized in the American Upper Cretaceous and throughout the European Tertiary. At the present time its numerous species are confined to the American tropics. In the Wilcox it has seven well-marked species, which are abundant individually, some ranging from Mississippi to Texas and from the base to the top of the Wilcox. The genus is probably of American origin and it has been a member of the flora of the American tropics from the Upper Cretaceous to the present.

The genus *Nectandra* with about seventy existing species confined to tropical and subtropical America probably has its geologic

history entangled with the fossil forms referred to Laurus. It occurs in the American Upper Cretaceous and the European and South American Tertiary. There are at least five characteristic Wilcox species some of which were abundant along the Wilcox coasts and some range from the base to the top of the deposits. Like *Oreodaphne* this genus appears to have been of American origin, becoming cosmopolitan in the Tertiary and restricted to its original home during the Pleistocene, where it is still a vigorous and much differentiated type.

The tribes Eusideroxyleæ, Litseeæ, Apollonieæ, Acrodiclidieæ, Laureæ and Cassytheæ do not appear to be represented in the Wilcox flora although the Litseeæ are represented in the Upper Cretaceous of the Mississippi embayment area and the Laureæ are common in the American Upper Cretaceous.

The tribe Cryptocaryeæ, now largely American, is represented in the Wilcox by a single well-marked species of *Cryptocarya*. The existing species of *Cryptocarya* number about 40 of which ¼ are South American and the balance Oriental. Only two or three fossil species are known. These come from the Tertiary of Australia and the Pleistocene of Java.

The form genus *Laurus* which serves to render insecure the discussion of the geologic history of the preceding genera includes a very large number of fossil forms of which no less than 25 are Cretaceous, the oldest being from the Albian of France and Portugal. Species of *Laurus* are abundant throughout North America in the Cenomanian, ranging northward to Greenland and also occurring in Europe and Australia. They have over a score of species in the Eocene and with a similar wide range. The 30 or more Oligocene species are confined to Europe. Over 30 Miocene species are confined to Europe and America and the score of Pliocene species are Mediterranean and largely Italian.

I will mention only one other genus since it definitely shows a past history that is probably typical of a large number of genera of Lauraceæ. The genus *Sassafras*.[42] monotypic and confined to North America in the existing flora, belongs to a large tribe—the Litseeæ, which today is chiefly Oriental, ranging from Asia through Malaysia

[42] See Berry, *Bot. Gaz.*, Vol. 34, 1902, pp. 426–450, tf. 1–4, Pl. 18.

to Australia. *Sassafras* has well-marked foliar characters of both form and venation that render it readily recognizable in the fossil state. Upwards of two score fossil forms have been described. The oldest of these are three well marked species in the Patapsco formation (Albian) of the Middle Atlantic slope in Maryland and Virginia. A species is recorded from this horizon in Portugal but the identification is very doubtful as is that of a Cenomanian species described from Bohemia, which latter probably represents the genus *Sterculia*. In America on the other hand the genus is widespread and well differentiated at the base of the Upper Cretaceous, ranging from Greenland along the coast and in the interior to South America and with about a dozen known species. By Eocene times *Sassafras* had reached Europe[43] probably by way of the Arctic regions, where it has been found throughout the Oligocene and Miocene. In the Pliocene the European forms had retreated southward but remained common in Italy, France and Spain. The glaciation of the Pleistocene caused their extinction on that continent, the single existing species surviving today in the original home of the genus.

The order Myrtales as developed in the Wilcox flora contains 11 species of Myrtaceæ, 9 species of Combretaceæ, 1 species of Trapaceæ and 1 species of Melastomaceæ, as against over 7,000 species in the existing flora.

The family Myrtaceæ has over 3,100 existing species separated by taxonomists into 2 subfamilies. The first of these the Myrtoideæ with 32 genera and about 2,400 species comprises mostly tropical forms of which over 75 per cent. are confined to the western hemisphere. There are over 200 in Asia, one of which extends into southern Europe, about 75 in Africa, about 200 in Australia, and about 60 in Oceanica. Nineteen of the genera are confined to America and these include the only monotypic genera in the subfamily, three in number, as well as large and greatly differentiated genera like *Myrcia* with upwards of 450 species. The two other large genera, *Myrtus* with 178 species and *Eugenia* with about 1,300 species, are the only two genera found on all the continents and in these two genera America furnishes 135 species of *Myrtus* and 850 species of *Eugenia*, or over 60 per cent. The second subfamily, the Leptosper-

[43] A very doubtful form is recorded from Australia.

moideæ, comprises the Leptospermæ with 28 genera and about 700 species and the Chamæleucieæ with 12 genera and about 165 species. Both of these tribes are even more strikingly Australian than the Myrtoideæ are American. The Chamnæleucieæ are entirely Australian and mainly confined to western Australia. The Leptospermæ have a single monotypic genus in Chili and the distribution of the other members of this tribe suggest the probability that it should be placed in some other alliance, since with the exception of *Metrosideros,* which is represented in Africa, and the genus *Baeckea* which reaches the Asiatic mainland, all of the genera are confined to Australia or the surrounding islands southeast of Asia.

In a recent paper Andrews[44] has presented some interesting statistics of distribution and an ingenious theory of the history of the family. He considers that the original stock was arborescent or shrubby with entire, simple, opposite, penniveined leaves with dots and intra-marginal acrodrome veins; with the calyx lobes and petals imbricate, probably in fives: flowers regular, solitary or in cymes; stamens indefinite, numerous, free, with versatile, 2-celled anthers; ovary inferior with two or more cells; style simple; fruit inferior, crowned with persistent limb of calyx, indehiscent, succulent or fleshy (rarely dry); albumen none; cotyledons thick and fleshy, with a short radicle.

From the character of Cretaceous climates this or some other theoretical prototype flourished in a mesophytic environment. Among modern groups the nearest approach to this theoretical stock is furnished by the Myrtoideæ which are fleshy fruited, most numerous in species, and widely spread in the equatorial regions, with over 75 per cent., however, confined to America. The existing Myrtaceæ with capsular fruits representing the extreme of specialization in the family are Australian while the Chamælaucieæ standing in an intermediate position between the two preceding groups are almost wholly confined to western Australia.

These are the facts of modern distribution. Their interpretation may be various. Andrews (op. cit.) from a study of the present distribution, geologic climates and the geological history of the Austra-

[44] Andrews, E. C., "The Development of the Natural Order Myrtaceæ," *Proc. Linn. Soc. N. S. Wales,* Vol. 38, Pt. 3, 1913, pp. 529–568.

lian region, concludes that the Leptospermoideæ originated from the Myrteæ, and that the Cretaceous forms were widespread which latter was undoubtedly the case. That before the separation of Australia from the Asiatic mainland fleshy-fruited forms found themselves in a region of warm moist climate but relatively poor soil and that it was this edaphic factor that was the principal stimulus to the differentiation of the Leptospermoideæ, which with the exception of the genus *Metrosideros* show adaptations to poor soil and temperate or dry climates and this exception explains the relatively wide distribution of *Metrosideros* from Asia to the Fiji Islands. The *Eucalyptus* forms according to the view of this student were derived from *Metrosideros* after the separation of New Caledonia from Australia and the latter continent from Asia. To support this latter point Andrews is obliged to consider all of the Cretaceous identifications of *Eucalyptus* and all of the Tertiary identifications outside of Australia as equally misleading. With regard to the presence of *Eucalyptus* in North America I think this contention to be not unlikely, for although in accordance with paleobotanical usage, I have identified numerous forms of *Eucalyptus* in the North American Upper Cretaceous, I have long thought that these leaves represented ancestral forms of *Eugenia* or *Myrcia,* but have hesitated suggesting any change in nomenclature from the havoc it would play with stratigraphic paleobotany.

The supposed American Cretaceous fruits of *Eucalyptus* have long since been shown to be referable to *Dammara*-like forms and in my studies of the Tertiary flora I have scrupulously refrained from referring any of the numerous myrtaceous leaves to the genus *Eucalyptus.* Regarding the possible occurrence of *Eucalyptus* in Europe I am not sure that the identifications of Heer, Unger and Ettingshausen are erroneous. Certain remains considered as *Eucalyptus* fruits seem very convincing from the published figures and there is not the slightest doubt that the other great modern Australian alliance—the Proteaceæ—was represented in both Europe and America during the Cretaceous and Tertiary. There is one additional argument against the Cretaceous radiation and the paleobotanical determination of *Eucalyptus* and that is the great persistence of the peculiar juvenile, opposite, cordate, sessile and horizontal leaves which

must represent an ancestral character of long standing before the evolution of the falcate leaves of the genus with twisted leafstalks and other xerophytic features.[45]

I have dwelt at some length on this question because of its phylogenetic importance and the possible bearing of the Wilcox flora on this point. In considering the morphology of the existing species, *Eugenia* has many claims to be considered the most primitive although *Myrcia* is almost equally old and is certainly closely related to *Eugenia*. Among the numerous Cretaceous fossils from North America now referred to *Eucalyptus* there is not a single one that does not exhibit characteristic features of *Eugenia* or *Myrcia*, especially the latter, a fact greatly impressed on me in handling a large amount of recent material during my study of the Wilcox forms.

In the Wilcox flora there are six well-marked species of *Myrcia* and four nearly equally well marked species of *Eugenia* as well as a single species of *Calyptranthes*. The latter genus appears also to be represented in recent collections from the Isthmus of Panama. Without pursuing the subject beyond the known facts, confessedly meager, and noting the presence in the Wilcox flora of numerous Combretaceæ and a representative of the great tropical family *Melastomaceæ*, largely American in the existing flora, both of which are families closely related morphologically to the Myrtaceæ, it would seem that the known facts, as well as the law of probabilities, suggest America as the original home of the family. That it reached Europe either by way of Asia or the North Atlantic plateau early in the Upper Cretaceous and became cosmopolitan before the close of the Cretaceous. During the late Tertiary this ancestral stock, which largely coincided with the existing subfamily Myrtoideæ, was forced to withdraw from temperate North America to the American tropics, where it had originated and to which it has since been so largely confined. The types peculiar to the Australian region represent the relics of the Cretaceous radiation with numerous new types evolved on that continent as Andrews has suggested. This is exactly the

[45] See Deane, H., "Observations on the Tertiary Flora of Australia," *Proc. Linn. Soc. N. S. Wales*, Vol. 15, 1900, pp. 463–475; Cambage, R. H., "Development and Distribution of the Genus *Eucalyptus*," Presidential Address, *Jour. Proc. Roy. Soc. N. S. Wales*, 1913.

reverse of the hypothesis proposed by Deane (op. cit.) but one that accords far better with the facts not only of geologic history, but with those of existing distribution.

As is pointed out in the systematic part of this work all of the Wilcox forms are coastal types closely related to existing American species of similar habitat. About 150 fossil forms have been referred to the Myrtaceæ, one third at least having been described as species of *Eucalyptus*. At least half of these occur in the Cretaceous of all parts of the world, but particularly throughout the northern hemisphere. They are especially well represented in North America and the possibility that they are ancestral forms of *Myrcia* or *Eugenia* has already been pointed out. A similar widespread distribution but less specific variation characterizes the Eocene forms that have been referred to *Eucalyptus*. The Oligocene records are all European and the Miocene records include both Europe and Asia.

The genus *Myrtus* has about 24 fossil species, all European, the majority being almost equally divided between the Oligocene and the Miocene. The oldest forms are early Eocene but the form-genus *Myrtophyllum* Heer has several Upper Cretaceous species in Europe, America and Australia, as well as Tertiary species in Europe, Asia and South America.

The genus *Myrcia* DC. so well represented in the Wilcox flora has species in the European Oligocene, four species in the early Tertiary of Chili and one in the Pliocene of Brazil.

The genus *Eugenia*, also prominent in the Wilcox flora, has its oldest known species in the Dakota sandstone. It is represented in Europe throughout the Tertiary from the lower Eocene to the Pliocene.

The genus *Callistemon* R. Brown has been identified in both the Upper Cretaceous and Tertiary of Europe and no less than 25 species have been referred to the genus *Callistemophyllum* Ettingshausen. These include Upper Cretaceous forms in America and Europe, Eocene forms in Greenland and Australia, and numerous Oligocene and Miocene species in Europe.

Leptospermum, *Leptospermites* and *Leptospermocarpum* have been identified from the Upper Cretaceous and Tertiary of Europe: *Tris-*

tania-like fruits have been described as *Tristanites* by Saporta from the lower Miocene of France: the genus *Psidium* Linné, with about 100 modern species in the West Indies and Mexico, is represented in Chili by an early Tertiary species: and finally the genus *Metrosideros* has been identified in the Atane beds of Greenland and in both the Oligocene and Miocene of Europe.

The family Combretaceæ (Terminaliaceæ) embraces about 16 genera and 285 existing species of shrubs or trees and tropical vines, with simple, entire, coriaceous, persistent, exstipulate, alternate or opposite leaves. The inflorescence is racemose or capitate and the flowers are regular, perfect or polygamous, often apetalous. The stamens are two or three times as numerous as the petals and the one-celled ovary develops into a drupaceous or berry-like indehiscent fruit, often crowned with the accrescent calyx and containing a solitary seed without endosperm.

The existing species are all tropical or subtropical, ranging from 34° north to 35° south latitude, and a relative large number are littoral or strand types. The various continental areas have the following peculiar species: America 75, Africa 85, Madagascar 36, Asia 57, Australia 23. About ten or a dozen species are found in more than one area, there being a remarkable identity between the American tropics and those of West Africa, the genera *Cacoucia, Conocarpus* and *Laguncularia* having identical species in both regions.

The geologic history of the family is most incomplete, but it is exceedingly prominent in the Wilcox flora where it is represented not only by characteristic leaves but by flowers and fruits. No species are certainly known from horizons as old as the Upper Cretaceous although a species of *Termanaliphyllum* has been described from the Perucer beds (Cenomanian) of Bohemia and a species of *Conocarpites* from the Tuscaloosa formation of Alabama. So far as I know there are no authentic occurrences as old as those of the Wilcox. In this flora there are three well-marked species of *Combretum,* a genus with about 130 existing species found in all tropics except Australia and Polynesia. Over thirty of these are endemic in South America and their abundance in the Wilcox as well as the

occurrence of a species in the early Tertiary of Chili strongly suggests that the genus is of American origin. This statement as well as the determination of the Wilcox species receives confirmation in the remarkably preserved flower from these beds described as *Combretanthites*. *Combretum* has been recorded from the Miocene of Switzerland and Germany, and from the Pliocene of Italy. It occurs in the Claiborne group of the Mississippi embayment and Felix has described petrified wood from the supposed Eocene of the Caucasus which he calls *Combretacinium*.

The genus *Conocarpus* Gærtner, a member of the tropical mangrove association, has a well marked species in the Wilcox flora which is supposed to be descended from the *Conocarpites* described from the Tuscaloosa formation in this same general region. Another species very close to the modern form of the American tropics occurs in the Claiborne group. *Conocarpus* fruits have also been described recently from the Aquitanian of Rhenish Prussia.

The genus *Laguncularia* Gærtner, monotypic in the mangrove association of America and the west coast of tropical Africa, is represented by both leaves and fruits in the Wilcox flora. The only other genus of Combretaceæ with known fossil representation is *Terminalia* Linné It is a large genus in the existing flora with over one hundred species almost equally divided between America, Asia, Africa and Australia, several of the species being very wide-ranging littoral types. There are three Wilcox species, based on both leaves and fruit. One of the species makes its appearance in the underlying Midway group of the Western Gulf region, possibly representing the beginning of its extension northward along the coast in the embayment region from tropical America.

Five Oligocene species of *Terminalia* have been described from Europe, the determinations resting on both leaves and fruits, and the occurences ranging from the Sannoisian to the Chattian and geographically from southeastern France to Greece. There are seven well distributed Miocene species in Europe, as well as Pliocene species in both Spain and Italy along the shores of the Pliocene Mediterranean Sea. A supposed Pliocene species is also recorded from Bolivia.

While future discoveries will have to greatly amplify the fossil record before the history of the family in past times can be traced with any degree of surety, the remarkable display of these forms in the Mississippi embayment region, evidently derived from the American tropics, gives a large amount of probability to the theory that the family originated in the American tropics during the Upper Cretaceous.

The genus *Trapa* Linné, formerly included in the family Onograceæ, is now made the type and only genus of the family Hydrocaryaceæ (Trapaceæ, Dumort, 1827). There are three existing species, all aquatics, and all confined to the old world except for the naturalization of *Trapa natans* Linné, in New England and New York. The latter species is found irregularly scattered throughout central and southern Europe, its area of distribution being a contracting one as shown by its occurrence in post-glacial deposits at very many localities beyond its present range in Russia, Finland, Sweden and Denmark. The two other existing species are *Trapa bicornis* Linné of China and *Trapa bispinosa* Roxburg of southeastern and southern Asia (said also to occur in Africa).

The genus has an extended geological history. Rosettes supposed to represent the floating leaves (*Trapa ? microphylla* Lesq., and *Trapa ? cuneata* Knowlt.) are widespread in the Rocky Mountain province in beds of late Cretaceous and early Tertiary age. The oldest recognizable fruits are a large bi-cornute form from the Eocene of Canada and Alaska and *Trapa wilcoxensis* Berry found in the Wilcox flora. An Oligocene species (*Trapa Credneri*) Schenk has been described from Saxony, and no less than seven species have been described from the Miocene—two occurring in Idaho (Payette formation), one in Japan and the balance in Europe, where two species continue into the Pliocene. A species from the late Pliocene of America is found in southern Alabama. The existing *Trapa natans* has been recorded from the preglacial beds of England and Saxony and from very many interglacial and postglacial deposits in Portugal, Italy, Netherlands, Germany, Sweden, Russia and Denmark, Gunnar Andersson in a recent paper (1910) mentioning 18 localities in West Prussia, 6 in Denmark, 17 in Sweden and 29 in Finland.

The family Melastomaceæ is a relatively large one with about 150 genera and over three thousand existing species. It is almost strictly tropical although some members range southward to 40° south latitude. It is a typically American family, seven of the fifteen tribes into which the family is divided being confined to tropical America, and about 2,500 of the existing species being also endemic in this region. While the geologic history of this vast assemblage of forms is practically unknown, there is no evidence to disprove the theory that it, like the allied families Combretaceæ and Myrtaceæ, had its origin in that most prolific region—the American tropics.

The few fossil forms that have been found, including leaves, flowers and calices, have been referred to the form-genus *Melastomites* first proposed by Unger. A doubtfully determined species, which probably belongs to the Lauraceæ, had been recorded from the Upper Cretaceous of Westphalia. The only known Eocene species is the well-marked form present in the Wilcox flora. Four Oligocene species have been described from Bohemia, Styria and Egypt; four Miocene species from Switzerland, Prussia and Croatia; and a Pliocene species from Italy.

The order Umbellales (Umbellifloræ of Engler) includes but three families—the Araliaceæ, Umbelliferæ and Cornaceæ, together with upwards of 3,000 existing species of which more than two-thirds belong to the Umbelliferæ. The three families are closely related and stand somewhat apart from the rest of the choripetalous orders. While undoubtedly there has been great specific variation in very modern times especially among the herbaceous forms of Umbelliferæ, some members of the alliance go back as far as undoubted dicotyledons have been found, and this fact is one of the strongest arguments for considering its relationships to the Gamopetalæ to be less close than some botanists have suggested, a suggestion based primarily on a consideration of the floral structures apart from the morphological features of the whole plants As regards floral evolution the Umbellales clearly mark its highest expression among the Choripetalæ and parallel the Gamopetalæ. The flowers are epigynous, with cyclic stamens, reduced carpels, and often reduced sepals. The Araliaceæ and Cornaceæ are both positively and the Umbelliferæ doubtfully represented in the Wilcox flora.

The family Araliaceæ contains about 52 genera and 500 existing species, chiefly inhabitants of the tropics, the notable exceptions to this statement being in North America and eastern Asia. The modern center of development is in the Asia-Australia region, no less than 33 genera being confined to Asia, Malaysia, Australia or Polynesia. Africa has three peculiar genera with about 30 species; America has five peculiar genera with about 100 species. The genus *Schefflera* is cosmopolitan. *Hedera* and *Polycias* occur in Eurasia and Africa. Two genera are common to Asia and America and *Aralia* adds Australia to a similar distribution. *Pseudotenax* with about six species is peculiar to western South America and New Zealand.

The fossil record is not nearly as complete as it should be to afford a secure basis for generalizations. A number of genera are found, however, in the oldest deposits in which undoubted dicotyledons are known. The largest genus is *Aralia,* commonly used by paleobotanists as a form-genus for generically unidentified species of Araliaceæ, rather than for forms falling within a strict modern definition of *Aralia.* No less than fifty species of *Aralia* have been described from the Cretaceous. Two of these come from horizons as old as the Albian of Portugal. In beds of similar age in eastern America (Maryland and Virginia) there are two well-marked species referred to *Araliæphyllum* and clearly ancestral to the numerous species of *Aralia* so common in the Upper Cretaceous of the latter region. Very similar, in some cases identical, forms are found in the Cretaceous on both sides of the Atlantic. There are fifteen species in the Perucer beds (Cenomanian) of Bohemia and Moravia and a like number in the Dakota sandstone of the western United States, while along the east coast there are nine species in the Raritan formation, eight in the Magothy formation, and one each in the Black Creek formation of North Carolina, the Eutaw formation of Georgia, the Tuscaloosa formation of Alabama and the Woodbine sand of Texas. In Greenland there are two species in the Atane beds and a third in those of Patoot. In the younger Cretaceous there are two species in Bohemia, two in Westphalia and one in Colorado. Australia has a species and ten supposed varieties of *Aralia* in the Upper

Cretaceous beds of that country. In addition to the foregoing display, the allied genus *Araliopsis* (Berry 1911) has a number of well-marked species in the Raritan, Magothy and Dakota formations, so that it must be conceded that the araliaceous stock was well differentiated and cosmopolitan before the close of the Cretaceous.[46]

There are over a score of Eocene species of *Aralia,* they being especially common in the Fort Union of the western United States, the Paleocene of Belgium, and the Eocene of Australia. The three Wilcox species are not common—two of them are common Fort Union species and the third was described originally from western Greenland. In addition there are species in the Denver formation, the Green River formation, in Oregon, New Zealand, Italy, and the south of England.

There are upwards of twenty Oligocene species, especially in the Sannoisian of southeastern France from which 14 species have been described. All of the other Oligocene records are also European.

There are also about twenty Miocene species distributed over North America, Europe and Asia. Some of the California species, *e. g., Aralia Whitneyi,* are clearly ancestral to existing Asiatic east-coast forms. A fruit (*Araliæcarpum*) is described from the Miocene of Prussia. There are in addition between 15 and 20 fossil species of *Aralia* more or less doubtfully connected with other genera of the family, *e. g.,* there is a species of *Arthrophyllum* doubtfully identified from the upper Oligocene of France; a species of *Cephalopanax* (?) is recorded from the lower Miocene of France; several forms of *Sciadophyllum* (?) occur in Greenland, Bohemia and France; and *Paratropia* (?) is recorded from the Paleocene, Oligocene and Miocene of France and the Miocene of Bohemia.

There are two species of *Oreopanax* in the Wilcox flora, one of them exceedingly well marked and clearly referable to the section Digitatæ of *Oreopanax.* The latter genus has about eighty existing species with simple, lobate and digitate leafed sections confined to tropical America but present in the Paleocene, Tongrian and Aquitanian of France. The modern Asiatic genus *Acanthopanax* Decaisne and Planchon has Oligocene species in France and Germany, and a Miocene species in Japan.

[46] See Berry, "Aralia in American Paleobotany," *Bot. Gaz.,* Vol. 36, 1903, pp. 421–428.

The genus *Panax* Linné with about six existing species in Asia and North America has furnished a number of fossil forms based on numerous characteristic fruits as well as leaves. It is represented from Greenland to Alabama along the west coast of the Atlantic and in the Perucer beds of Bohemia (*Araliphyllum*). It has five species in the Oligocene of Europe and six Miocene species in Europe and Colorado. The genus *Cussonia* Thunberg with about 25 African species in the existing flora is doubtfully recorded from the Albian of Portugal. It is present in the Perucer beds of Bohemia (*Cussoniphyllum*) and in the Oligocene of France and Greece.

The genus *Hedera* Linné with only three existing species of Europe, Asia and Africa has numerous and well-defined fossil forms.[47] No less than fifteen have been described from the Upper Cretaceous of both America and Europe. There are about seven Eocene species in Greenland, Alaska, the Fort Union of the western United States, and in the Paleocene of Belgium and France. The genus remains common during the Tertiary in Europe and is present in America as late as the Upper Miocene lake of Florissant, Colorado. The anecestor of the existing *Hedera helix* Linné occurs in the Pliocene of central France and the modern form itself is found in the Pleistocene of England, France and Italy. A species of *Polyacias* occurs in the Pleistocene of Java associated with *Pithecanthropus erectus*.

The family Umbelliferæ with 170 genera and upwards of two thousand existing species is distinctly an extratropical family with numerous boreal forms. The majority are herbaceous and of relatively modern origin. It is very sparingly and doubtfully represented in the fossil state and the only Wilcox form that suggests such an affinity is the fruit described as *Carpolithus prangosoides* which greatly resembles those of the existing genus *Prangos* Lindley.

The third family of the Umbellales, the Cornaceæ, is a relatively small one, with only sixteen genera and about 100 existing species, mostly of the temperate zone. The fossil forms are confined to the two genera *Cornus* and *Nyssa*. *Cornus* has about 40 existing species of herbs and small trees mostly confined to the north temperate zone

[47] The forms from the Potomac group of Maryland and Virginia described by Fontaine as species of *Hederæphyllum* are entirely worthless.

in Eurasia and North America but represented in Mexico, and with a single species in Peru. Over fifty fossil species have been described. There are at least twelve in the Upper Cretaceous, all confined to North America and ranging from Greenland to Alabama. There are about a dozen Eocene species in America, Europe, and the Arctic, one of these is sparingly represented in the Wilcox flora. Oligocene records are few in number but over 25 Miocene species have been described, the genus being particularly abundant at this time throughout central Europe but also represented in both North America and Asia. About five Pliocene species are recorded from Spain, France, Italy and Japan and the genus has afforded Pleistocene material in New Jersey, Holland, England, etc.

The genus *Nyssa* Linné (including also *Nyssidium* Heer and *Nyssites* Geyler and Kink.) comprises about seven existing species ranging from shrubs to large trees, natives of southeastern North America and eastern and central Asia. It has furnished over fifty fossil forms, the majority being based on the characteristic costate stones. The oldest known forms are from near the base of the Upper Cretaceous (Dakota, Tuscaloosa) of North America. By Eocene time *Nyssa* had reached Alaska, Greenland and Europe. There are two characteristic species in the Wilcox, both based on stones, and a third occurs in the overlying deposits of the Claiborne group. In the lignite deposit of Brandon, Vermont, of uncertain but probably early Tertiary age, no less than eighteen so-called species of stones have been described, and while doubtless the specific differentiation is overrefined, it emphasizes the abundance of *Nyssa* in New England at that time. *Nyssa* is abundant in the European Oligocene and there are Miocene species in New Jersey, Virginia, Europe, and Asia; and a Pliocene species occurs in Alabama. Some of the modern species are common in the Pleistocene of this country from New Jersey southward.

While much remains to be learned regarding the history of the Cornaceæ it seems clear that the two genera *Cornus* and *Nyssa* which have yielded fossil forms are both types that appear to have originated in North America during the Cretaceous.

No family of the Choripetalæ has succeeded in maintaining a

world-wide distribution as have several families of Monocotyledonæ and Gamopetalæ. No distinctly boreal group has been developed as among the Gamopetalæ (Ericales). Certain great families characterize the north temperate region and these are all herbaceous forms believed to be of relatively recent origin, e. g., Polygonaceæ, Caryophyllaceæ, Cruciferæ, Saxifragaceæ, Onagraceæ and Umbelliferæ. While aquatic forms are common this habit does not characterize whole families as among the Monocotyledonæ. The Choripetalæ predominate in the American tropics and many of the families present in the Wilcox flora have been shown to have probably originated in that region.

The second grand division of the Dicotyledonæ, the Gamopetalæ (Sympetalæ), constitute a rather well-defined group, presumably derived from the Choripetalæ, and characterized by a complete cyclic arrangement of the floral parts, a usually gamopetalous corolla, ovules with a small nucellus and usually a single integument. It contains nine or ten orders and upwards of 50,000 existing species. The majority of the orders appear to be more compact and natural groups than the corresponding alliances among the Choripetalæ. The Ericales, Primulales and Ebenales are pentacyclic and isocarpous, while the Gentianales, Polemoniales, Personales, Plantaginales, Rubiales, Valerianales and Campanales are tetracyclic and anisocarpic, the last three orders being epigynous.

The alliance predominates in herbaceous forms and several of the families are distinctly boreal. While the Compositæ, Labiatæ and Plantaginaceæ are of world-wide distribution there are no notable continental pairings such as is usually the result of an extended geologic history. These and many other facts suggest that the Gamopetalæ as a whole, especially the more evolved, herbaceous, extratropical families, are of relatively modern origin whose major specific differentiation was concomitant with the occupation of the temperate zones after the retreat of the Pleistocene ice-sheets.

From the viewpoint of floral structures the so-called Compositæ are clearly the culmination of the evolution of floral structures. This is shown not only by their gamopetaly, epigyny, connivent anthers, and the formation of seedlike fruits with a pappus, but by the complex flowerhead, the prevalence of diclinism, the dimorphism of the

corollas and other special features. This theorem is corroborated by the in general modernness of the alliance.

Six of the Gamopetalous orders are represented in the Wilcox flora. The first of these, the Primulales, in its fullest development in existing floras includes the three families Myrsinaceæ, Primulaceæ and Plumbaginaceæ. They are structurally much alike with a single cycle of stamens opposite the petals, and a unilocular ovary with a free central placenta. This community of floral organization can only be attributed to convergence and not to filiation since the Myrsinaceæ are old forms which in modern floras are predominantly tropical and American while the Primulaceæ are chiefly north temperate and boreal herbs of relatively recent evolution: and the Plumbaginaceæ are very modern halophytic herbs and undershrubs of salt beaches and steppes, the majority being found in the Mediterranean and Caspian regions.

The Myrsinaceæ, the only family represented in the Wilcox flora, is characterized by alternate, simple, coriaceous, punctate, exstipulate leaves; perfect, regular flowers; and single seeded drupaceous fruits.

The family contains about thirty genera and 530 species of shrubs or trees, largely tropical and predominantly American. Thus eleven genera containing upward of 200 species are peculiar to America while there are only four genera with less than a dozen species peculiar to Asia, and three genera with about 100 species peculiar to Africa.

The genus *Myrsine* Linné is found on all the continents except Europe and in Polynesia. Its distribution is extratropical in the African region. *Euardisia* Pax is found in all tropics. *Maesa* Forskal is found in all oriental tropical countries as is also the monotypic genus *Ægiceras* Gærtner, a member of the coastal mangrove association. The genus *Cybianthus* Martius, largely South American, has species in the Philippines and in New Grenada. There is little that is significant in the recent distribution of the family and the fossil record is very incomplete.

Over seventy-five fossil forms have been referred to *Myrsine*. The oldest are the seven or eight forms recorded from the Upper Cretaceous. All of the older of these (Cenomanian) are from North America and only one from the Turonian of Bohemia occurs in the

European Upper Cretaceous. The American forms are not varied specifically but are wide ranging and common, extending from the Atane beds of Greenland along the Atlantic coast to the Tuscaloosa formation of western Alabama as well as in the Dakota sandstone of the western interior.

The recorded Eocene species of *Myrsine* number seven or eight and include an Australian form, one in the early Eocene of Alum Bay, three in the upper Eocene of France, and two in western Alaska. *Myrsine* is exceedingly varied and abundant during the Oligocene throughout southern Europe, over thirty species having been described, of which eleven occur in the basal Oligocene of southeastern France (Sannoisian). There are upwards of thirty Miocene species throughout Europe, one in Colorado being the only known American occurrence. Several species linger in the Pliocene of southern Europe in France and Italy and one species is present in the Pliocene of Brazil. In addition to the forms referred to *Myrsine* several forms from the European Tertiary have been referred to the form-genus *Myrsinites*. Ettingshausen recorded a species of *Pleiomerites* from the Miocene of Bohemia; and the genus *Maesa* Forskal, which has about 40 modern species in Asia, Africa, Australia and Polynesia, is represented in the Oligocene of Transylvania and Egypt and in the Miocene of Styria.

The genus *Ardisia* Swartz (including *Ardisiophyllum* Geyler) has furnished about a dozen fossil species, the oldest of which, a very doubtfully determined form, comes from the Turonian of Bohemia. There is an Eocene or Oligocene species in Chili, three Oligocene species in Bohemia and one in Transylvania. There are four Miocene species in France, Bohemia and Styria; and Pliocene species in Italy and Borneo.

The genus *Icacorea* Aublet is the only member of the Myrsinaceæ found in the Wilcox flora. The genus has numerous existing species confined to South America. The fossil record is meager but includes two or three species of the European Oligocene. The Wilcox species is thus considerably older than any European occurrence. It represents a form which is very close to the modern *Icacorea paniculata* Sudworth, a shrub or slender tree of the Florida keys, Baha-

mas, Cuba and the east coast of southern Mexico. In addition to the foregoing records at least four kinds of flowers have been described from the Baltic amber (Sannoisian). These are *Berendtia* Gœppert (2 species), *Myrsinopsis* Conwenz, and *Senaelia* Gœppert.

While the geologic history of the family is thus so incomplete it is not without significance in this case as in the case of so many families previously discussed, that a predominantly American family in the existing flora has its oldest known fossil occurrences in the basal Upper Cretaceous of North America.

The order Ebenales includes the families Sapotaceæ, Ebenaceæ, Styracaceæ and Symplocaceæ, together with upward of one thousand existing species, the larger families being the Sapotaceæ and Ebenaceæ, both of which are represented in the Wilcox flora, while the other two families are sparingly represented in the European Tertiary. There is considerable range in floral structures from indefiniteness in the number of stamens and carpels and polypetaly, to a 4 to 8 cyclic arrangement, which leads floral morphologists to consider the order as among the most primitive of the Gamopetalæ.

The family Sapotaceæ comprises trees or shrubs with a milky juice and with alternate, simple, entire, mostly coriaceous, petiolate, exstipulate leaves. It contains about thirty-two genera and nearly four hundred existing species of all tropical countries. About half of the existing species are American. There are eleven genera confined to America, seven to Africa, three to Australia, two to New Caledonia, two to Asia and Malaysia, two to Malaysia and one to Asia. The three large genera, *Sideroxylon, Chrysophyllum* and *Mimusops,* are represented in all tropical countries. There are four genera and twelve species represented in the Wilcox flora. The largest of these genera is *Bumelia* Swartz with six well-marked Wilcox species. *Bumelia* with about a score of species is confined to America in the existing flora, ranging from the southern United States through the West Indies and Central America to Brazil. It has numerous fossil species, the oldest coming from the Upper Cretaceous (Dakota sandstone) of the western interior. In addition to the six Wilcox species, which are prototypes of still existing forms, there are two Eocene species (Ypresian) in southern England.

There are about a dozen Oligocene species, ten of which are widespread in Europe, one is found in the Apalachicola group of western Florida and two forms, representing both leaves and fruit, are found in the Vicksburg group of Louisiana and Texas. There are seven or eight Miocene species widespread in Europe and one is recorded from the late Miocene of Colorado.

The genus *Chrysophyllum* Linné with about sixty existing species found in all tropical countries, but the majority American, has a supposed species in the Upper Cretaceous of Saxony (Niederschœna); a well marked species in the Wilcox flora; three Oligocene and six Miocene species in Europe.

The genus *Mimusops* Linné with about 40 existing species in all tropics has three well-marked Wilcox species and a fourth in the overlying Claiborne deposits. To it has been referred a species from the Upper Cretaceous of Saxony (Niederschœna) and it is undoubtedly represented in the Upper Cretaceous of the embayment region as well as elsewhere by the leaves that have been referred to the form-genus *Sapotacites.*

The genus *Sideroxylon* Linné, with about eighty existing species in the oriental tropics and about fifteen in the American tropics, has two species in the Wilcox flora which are the oldest thus far discovered. To this genus have been referred four Oligocene and one or two Miocene species from Europe.

Isonandra Wright a small modern genus of the Malayan region is represented in the Tertiary of Borneo by *Isonandrophyllum* Geyler; the genus *Achras* Linné (*Sapota* Plumier), now monotypic in the West Indies, has three species in the European Miocene; *Labatia* Swartz, with six existing species in the American tropics, has been doubtfully determined in the Miocene of Prussia and Italy; and Felix has described two forms of petrified wood which he refers to this family under the name *Sapotoxylon,* one species from Germany and the other from an unknown locality and horizon.

A large number of fossil forms of Sapotaceæ have been referred to the form-genus *Sapotacites* proposed by Ettingshausen (also *Sapotophyllum*). There are at least ten Upper Cretaceous forms widespread in North America and represented in Europe in the Perucer

beds of Bohemia and the *Credneria* stage of southern Saxony (Cenomanian). Three of these Upper Cretaceous forms are from the Tuscaloosa formation of Alabama and undoubtedly represent the ancestors of some of the Wilcox forms. There are about ten recorded species of *Sapotacites* in the Eocene of Australia, France and southern England. There are about a score of species in both the Oligocene and Miocene, most of which are European. There is, however, an undescribed species in the Apalachicola group of western Florida. In the Pliocene there are species in southern Europe and on the island of Java.

Notwithstanding the incompleteness of the record it is obvious that the family became well differentiated during the Upper Cretaceous and while it would not be safe to assign its place of origin to the American region, it is probable that at least several of the genera, such as *Bumelia* for example, originated in this region.

The family Ebenaceæ includes about eight genera and upwards of three hundred existing shrubs and trees, of which over half are referred to the genus *Diospyros* Linné. The family is mainly tropical as are most of the species of *Diospyros,* but the latter is represented in the north temperate zone in eastern North America, eastern Asia, and the Mediterranean region. The three modern monotypic genera, *Tetraclis, Brachynema* and *Rhapidanthe* are confined respectively to Madagascar, Brazil and West Africa and none have been found fossil. The genus *Royena* is mostly South African; *Euclea* is entirely confined to Africa: *Maba,* a large genus, ranges from Africa eastward to Polynesia; and *Macreightia* is common to tropical Africa and America.

Diospyros with about 180 existing species is cosmopolitan. Between 90 and 100 fossil forms have been described. In that grand display of dicotyledonous genera which during the mid-Cretaceous replaced the old Mesozoic flora of ferns, cycads, and conifers and which appeared with such apparent suddenness at a number of points in the northern hemisphere, we find unmistakable evidence of the abundance and wide distribution of species of *Diospyros.* No less than seventeen different forms have been described from the rocks of this age, and the localities where they have been found are scattered

from Australia to Bohemia, Greenland, and Vancouver Island. A large majority of these species are American, and they seem to have been especially at home along the Cretaceous coast of the Atlantic and along the border of the Mediterranean sea which extended northwestward from the Gulf of Mexico over much of our present Great Plains area. One of these species, well named *Diospyros primæva* by Professor Heer in 1866, is especially widespread and abundant, being found not only in Iowa, Kansas, and Nebraska in the west but also from Texas eastward through Alabama and northward in South Carolina, North Carolina, Maryland, New Jersey, Long Island and Greenland, or from latitude 33° to latitude 71° north. That these early persimmons were not very different from those of today is shown by their similar foliage. This resemblance is also shown by the fossilized remains of the calices of various species. One of these calices from another early Cretaceous species, recently described by the writer, is *Diospyros vera,* found in what is known in the Potomac River valley as the Raritan formation. Apparently the habit of accrescence had not been fully formed but the calyx was persistent then as now and entirely like a modern calyx in appearance. It was four-parted as it usually is in existing persimmons, but other fossil forms had a five-parted calyx like a good many present day tropical species.

In the Eocene epoch, which succeeded the Cretaceous, the records of the fossil occurrences of *Diospyros* show that it was truly cosmopolitan. These records include about 20 species in Siberia, Alaska and Greenland on the north; Canada, various localities in Europe, as well as Colorado, Montana, Wyoming, Nevada, Oregon, Washington, and other western states. Unfortunately, we have no Eocene or later Tertiary records along the Atlantic coast of North America outside the embayment region since the preserved deposits are all of marine origin and contain no fossil plants. There is little doubt, however, that *Diospyros* continued to be an abundant element in the aborescence flora of this area.

There are two well-marked species of *Diospyros* in the Wilcox flora, one of which continues in this region through the Claiborne.

A large calyx is present in the Claiborne or Vicksburg of southwestern Texas.

There are about 24 Oligocene species, *Diospyros* being especially common throughout southern Europe. There is an American species of this age in the Apalachicola group of western Florida. The luxuriant forests of the Miocene have furnished about twenty species of *Diospyros,* the known distribution at this time includes European localities from Spain to Hungary and American records in Oregon, California, Yellowstone Park and Colorado. There are seven Pliocene species in southern Europe and in Java.

The allied genus *Royena* Linné has furnished splendidly preserved fruits from the oasis Chargeh in Egypt (Upper Cretaceous) as well as four Oligocene and two Miocene species in Europe. It seems never to have been cosmopolitan like *Diospyros,* since it has never been recognized in the western hemisphere. The fossil history of the genus *Euclea* Linné was evidently similar to that of *Royena, i. e.,* it makes its appearance in the basal Oligocene of Europe where it is represented throughout the Oligocene and Miocene, becoming confined to Africa in Plio-Pleistocene times.

The genus *Macreightia* DC. has nine or ten existing species, one occurring in tropical Africa and the balance being American. *Macreightia* is represented by both leaves and flowers in fossil floras and it has been a favorite receptacle for tripartite calices, not always of assured botanical identity. The oldest form is one in the German Oligocene and there are five or six species in the European Miocene. It has not been definitely recognized in North America, although some of the Wilcox material is not unlike some European material referred to *Macreightia.* Felix has recognized wood of this family (*Ebenoxylon*) in the Oligocene of the Island of Antigua.

The order Gentianales (Contortæ of Engler) includes six families with between four and five thousand existing species, the largest family being the Asclepiadaceæ with upwards of two thousand species. The families are complexly interrelated among themselves and with the next two orders, about the only constant characters being the opposite leaves and the generally twisted corolla in æstivation. The Asclepiadaceæ, not found in the Wilcox, shares with the

Apocynaceæ in the development of a latex-system and in other specializations, and the elaborate contrivances for entomophily in the former family reach a degree of complexity almost comparable with that of the Orchidaceæ. The Loganiaceæ, also not represented in the Wilcox flora, are lianas characteristic of South America and Asia and regarded by Engler as relatively primitive and possibly the ancestral stock of the Gentianales and Rubiales. The order as a whole is numerically massed in the tropics by reason of the many tropical genera of the two largest families—the Asclepiadaceæ and Apocynaceæ, which together contain three fourths of the existing species of the order.

The family Oleaceæ, sometimes considered as an order, the Oleales, contains 21 genera and about 400 existing species. There are three small genera peculiar to Asia and four peculiar to America, the remaining fourteen genera being found in more than one continental area. The three largest genera *Fraxinus* (40), *Mayepea* (50) and *Jasminum* (160) are all cosmopolitan. Eight of the twenty-one genera have been found fossil and it is evident that the family has an extended history, although there are no known Cretaceous records worthy of credence. Nor is the record well enough known to warrant generalizations. It is obvious from the early Eocene occurrence of leaves of *Fraxinus* associated with characteristic fruits, that the family must have been evolved before the close of the Upper Cretaceous but none of the genera have any well-marked or abundant known representation until Tertiary times.

The genus *Fraxinus* Linné has two species in the Wilcox flora, a characteristic samara, and foliage identical with that described by Heer from western Greenland as *Fraxinus Johnstrupi.* The latter furnishes an interesting instance of the extended distribution of members of the Eocene flora, at the same time illustrating the northward radiation of floras during the Eocene. Upward of ten additional Eocene species are known all of which are American and ranging from Tennessee to Alaska and Greenland. The Oligocene marks the appearance of the genus in Europe from which time to the present the genus has been represented throughout the warmer parts of the north temperate zone, at least four of the existing species making their appearance in the Pleistocene.

The second genus represented in the Wilcox flora is *Osmanthus* Lour. It has about ten existing species of eastern North America, eastern Asia and Polynesia. The Wilcox species is exceedingly close to *Osmanthus americanus* B and H of the Atlantic and Gulf coasts from North Carolina southward. A second fossil species is found in the Miocene of Florissant, Colorado.

The old world genus *Phillyrea* Linné is found fossil in Europe; the genus *Notelæa* Vent., which has six existing Australian species and an isolated remnant of its former distribution in Madeira and the Canary Islands, is represented in the Eocene, Oligocene and Miocene of Europe; the genus *Olea* Linné with over thirty existing species about equally divided between Africa, Asia, and Australia and Polynesia, has about twenty fossil forms (including *Oleophyllum* Conwenz and *Oleæcarpum* Menzel) in Europe where they range in age from the basal Eocene through the Oligocene, Miocene and Pliocene to the Pleistocene. The genus is not known in American fossil floras but there is a supposed species in the early Tertiary of Australia.

The genus *Ligustrum* Linné with about 35 existing species in southeastern Asia and the East Indies has three species in the Oligocene and Miocene of Europe.[48] Saporta has described representatives of the genus *Syringa* Linné from the Sannoisian of southeastern France, the occurrence of the latter genus being based on floral remains.

The family Apocynaceæ comprises 133 genera and between ten and eleven hundred existing species of perennial herbs, vines, shrubs and trees, mostly with a milky acrid juice and simple exstipulate leaves. The fruit is usually a pair of follicles or drupes and the seeds are often comatose. The family is almost equally divided into two subfamilies, the Plumeroideæ having 68 genera and about 550 species and the Echitoideæ having 65 genera and about 500 species. The genera *Plumeria* Linné with about 40 species, and *Rauwolfia* Linné with about 45 species, are cosmopolitan, mostly tropical; and 24 genera with about 300 species occur in more than one continental area. America with 36 peculiar genera containing about 325 species

[48] A species of *Ligustrum* recorded by Hollick from the Upper Cretaceous of Long Island is probably a *Pisonia*.

heads the list, followed by Africa with 28 peculiar genera containing about 130 species, and Asia with 20 peculiar genera containing about 75 species. Australia has few endemic genera or species, but numerous genera range from Asia or Africa to the Australian region and several genera are peculiar to Malaysia and to Polynesia. In the present state of our knowledge the distribution does not furnish material for generalization.

The fossil record, although including the representatives of at least a dozen genera, is too incomplete to shed much light on the history of the family or its existing distribution. The largest fossil genus is the form genus *Apocynophyllum* proposed by Heer and embracing fossil forms resembling *Thevetia, Cerbera, Apocynum* and other existing genera of the family. Five species are recorded from the Upper Cretaceous, coming from the Dakota sandstone, Australia, Westphalia and Saxony. There are over a score of Eocene species widely distributed. There are five species in the Wilcox flora some of which are exceedingly well marked and common. There are also five species in the Ypresian of southern England. Other Eocene records include Greenland, Australia, New Zealand and Chili. The score or more of known Oligocene species are confined to European localities. The Miocene species number about 25, all confined to Europe except a form recorded from Italy.

Fossil forms have been sparingly referred to the following genera: *Allamanda, Hæmadictyon* and *Thevetia* have been recognized by Engelhardt in the early Tertiary of Chili: *Alyxia, Alstonia, Cerbera* and *Tabernæmontana* have been recognized in the European Tertiary by various students: the genus *Neritinium* Unger has four or five species in the European Miocene: the genus *Plumeria* has four Miocene species in Europe and a Pliocene species in Brazil. The genus *Echitonium* Unger has over a dozen fossil species. There are five in the Eocene including a well marked form in the Wilcox flora; two in the Oligocene and five in the Miocene of Europe.

The genus *Nerium* Linné has only three or four existing species of shrubs or trees in the warmer parts of Eurasia. However the commonly cultivated *Nerium oleander* Linné of the Levant grows to a relatively large size and is extensively naturalized in Florida and the West Indies. It is used for hedges in Bermuda. Saporta re-

corded an Upper Cretaceous species, *Nerium Röhlii,* from the Campanian of Westphalia but this is almost certainly a member of the Myrtaceæ and not a *Nerium*. Undoubted species do occur in the Eocene of Europe, including the remains of a characteristic flower from the Paris basin. There are several Oligocene and Miocene species in Europe and the existing *Nerium oleander* or its immediate ancestor occurs in the Pliocene of southern Europe in France and Spain. The Wilcox species *Apocynophyllum tabellarum* is very suggestive of *Nerium* but the genus is not certainly known in the western hemisphere.

It may be noted that with the exception of the not certainly identified species of *Apocynophyllum* the family is not represented in the abundant known Upper Cretaceous floras of the world, which might mean that it originated somewhere in the southern hemisphere.

The order Polemoniales or Tubifloræ[40] contains the four families Convolvulaceæ, Polemoniaceæ, Hydrophyllaceæ and Borraginaceæ. The first three are characteristically American, the Convolvulaceæ being chiefly tropical, while the largest family, the Borraginaceæ, is typically developed in the north temperate zone.

The family Borraginaceæ, the only one of the order known in the Wilcox flora, contains about 85 genera and 1,600 existing species of mostly widely distributed north temperate herbs and shrubs, or trees in tropical countries, characterized by alternate, exstipulate, mostly entire leaves. The known fossil forms are few in number and of slight significance and comprise for the most part Tertiary remains described as species of *Borraginites* and *Heliotropites*. The family is represented in the Wilcox by two species of *Cordia,* a genus containing about 230 existing species of shrubs and trees of the warmer regions of both hemispheres, especially the western. There is a species in the Upper Cretaceous of the Misssissippi embayment area (Tuscaloosa formation) and a Miocene species in Europe. Early Tertiary forms are recorded from Chili by Engelhardt and from Tasmania by Ettingshausen. The slight evidence available indicates that the genus originated in the American tropics and that the bulk of the family is of late Tertiary origin.

[40] Not the Tubifloræ of Engler which includes the orders Polemoniales and Personales, here regarded as distinct.

The order Personales or Labiatifloræ includes sixteen families distinguished from the Polemoniales by the zygomorphism of the flowers. The specific differentiation is great and the lines of descent are confusing. The largest families are the Labiatæ with over 3,000 existing species, the Scrophulariaceæ with about 2,500, the Acanthaceæ with about 2,000, and the Solanaceæ with about 1,800. Two of the sixteen families, the Verbenaceæ and Solanaceæ, are represented in the Wilcox flora.

The family Verbenaceæ includes about 73 genera and 1,300 existing species of widely distributed herbs, shrubs, or in tropical countries trees. The family is largely tropical or subtropical and is notably represented in the South American region. The fossil record is most incomplete. The largely old world genus *Clerodendron* Linné is unmistakably present in both the Eocene and Oligocene of Europe, and Ettingshausen has referred, somewhat doubtfully determined forms from the European Miocene to the American genus *Petræ* Linné and to the cosmopolitan genus *Vitex* Linné. The genus *Citharexylon* Linné has about twenty existing species ranging from the Florida keys and lower California through the American tropics to Bolivia and Brazil. A single species found in the middle and upper Wilcox is extremely close to the existing *Citharexylon villosum* Jacquin, a small coastal tree of the Florida keys, Bahamas and Antilles. With the exception of one or two doubtfully determined forms in the Miocene of southeastern Europe it is the only known fossil form.

The genus *Avicennia* Linné sometimes made the type of a distinct family, the Avicenniaceæ or Black-mangrove family, includes from three to thirty existing species according to the varying interpretation of different students. They are found on all tropical tidal shores. Two species have been recognized in the Wilcox flora, one based on leaves and the second on a not conclusively identified capsule.

The family Solanaceæ includes about seventy genera and about 1600 existing species, widely distributed and largely tropical, but extending into the temperate zone, notably in the western hemisphere. They comprise herbs, shrubs, vines, or in tropical countries often trees, with opposite, stipulate, toothed, lobed or dissected leaves.

Their fossil history is almost entirely unknown. The single Wilcox representative of the family is a flower described as *Solanites,* a genus founded on the somewhat younger remains of a similar flower found in the Sannoisian of France, and comparable with the existing South American genus *Saracha* Ruiz & Pavon, as well as with *Witheringia, Solanum,* etc.

The last order of Gamopetalæ positively recognized in the Wilcox flora is the Rubiales which includes over 5,000 existing species segregated into five families, over four fifths being referred to the family Rubiaceæ—the only one represented in the Wilcox.

The Rubiaceæ includes about 355 genera and over 4,500 existing species of herbs, shrubs and trees; with simple, opposite or verticillate, mostly stipulate, leaves. They are widely distributed and largely tropical. While the Wilcox representation is confined to a single species each of *Exostema, Psychotria* and *Guettarda,* great interest must attach to the fossil record of so highly organized a family which is my justification for introducing the following brief sketch of our knowledge of it.

No less than twenty-five genera have been recognized in the fossil state. With the exception of the very doubtful determination of a species referred to *Rubiæphyllum* from the Turonian of Bohemia and doubtless representing a species of Ericaceæ, the family is unknown in the Upper Cretaceous. It is however represented in the early Eocene both in America and Europe. The Wilcox forms represent a species of *Exostema* Rich., close to the existing *Exostema caribaeum* R. & S. which ranges from the Florida keys to Central America. The genus comprises about twenty existing species of shrubs and small trees confined to the tropics and subtropics of America. The second Wilcox species is referred to *Guettarda* Endlicher, a genus of about fifty species mostly confined to the American tropics but including one or two cosmopolitan tropical maritime species. The Wilcox form is very close to the existing *Guettarda elliptica* Swartz, a small tree of the Florida keys, Bahamas and West Indies. The third Wilcox species is *Psychotria grandifolia* described originally by Engelhardt from the early Tertiary of Chili. The genus *Psychotria* Linné comprises about 350 existing species of shrubs and small trees in tropical America. Asia and the East Indies, two thirds

of its species being American. The fossil form is compared with *Psychotria grandis* Swartz of the American tropics.

The genus *Coussarea* Aublet with about 40 existing species in the Brazilian region has been identified by Engelhardt from the early Tertiary of Chili. The genus *Hoffmannia* Swartz with about a score of existing American herbs or shrubs, mostly confined to Central America, has a fossil species in the early Tertiary of Chili. Likewise the genera *Sabicea* Aublet and *Gouatteria* Martius each have a single species in the Tertiary of Chili.

The Baltic amber (Sannoisian) has yielded a flower referred to *Sendelia* and a leafy twig referred to *Enantioblastos*. The genus *Galium*, comprising over 250 widely distributed existing herbaceous forms, has been doubtfully identified from the Eocene of Greenland. Its fruits are also not uncommon in Pleistocene deposits. The genus *Randia* Houst., embracing about one hundred existing species of shrubs or trees in all tropics, is identified by a fruit in the Aquitanian of Rhenish Prussia.

The genus *Rubiacites* so named by Webber from its resemblance to the existing forms of *Rubia* Linné has furnished three species of leaves and flowers in the Aquitanian of Prussia and Switzerland. The genus *Gardenia* Ellis, containing about sixty species of shrubs or rarely trees of the eastern hemisphere, is represented by characteristic fruits in the Sparnacian of France, the Aquitanian of Germany and England, the Miocene of Baden and Italy, and the Pliocene of Italy. The genus *Posoqueria* Aublet, which includes five or six existing South American shrubs or trees, is represented according to Unger by both leaves and fruits in the Miocene of Croatia. The genus *Ixora* Linné with one hundred existing species of shrubs and small trees in all tropics is likewise recorded from the Miocene of Croatia, as is also *Pavetta* Linné, a genus with about seventy existing species of shrubs or small trees of the Oriental tropics, which has furnished both leaves, flowers and fruits from the celebrated plant and insect beds of Radoboj in Croatia.

The genus *Coprosoma* Forst., with 40 existing species in Australia, New Zealand and Oceanica, was recorded by Ettingshausen from the Tertiary of Tasmania.

The genus *Nauclea* Linné, which has about thirty existing species

of shrubs and trees in tropical Asia and Oceanica, was identified by Unger in the European Miocene and petrified wood of this type (*Naucleoxylon*) was described by Crié from the Pliocene of Java.

The genus *Morinda* Linné has about thirty existing species in all tropics, especially in the Orient and the Pacific islands. A fossil species has been recorded from the Oligocene of Italy and five additional species based on leaves have been described from the Miocene of Croatia.

A fruit from the Tertiary lignites of Brandon, Vermont, has been described by Perkins as *Rubioides* and another from the Aquitanian of Rhenish Prussia by Menzel under the name *Rubiaceæcarpum*. Geyler has identified the old world genus *Grumilea* Gærtner in the Tertiary of Borneo, and finally the genus *Cinchonidium* proposed by Unger for fossil fruits and leaves which were very similar to those of the existing South American genus *Cinchona* Linné, has furnished a number of species. There are four or five in the Eocene, including the Fort Union of the western United States and the Ypresian of England; five in the late Oligocene of southeastern Europe; about eight Miocene species, one coming from the Esmeralda formation of Nevada and the balance being European.

The family is thus seen to have been well represented in fossil floras throughout the Tertiary, but the small proportion of the existing genera with fossil representatives and the incompleteness of the record of those with fossil representatives renders untrustworthy any generalizations that might be made from the present facts.

Under *Incertæ sedis* are grouped fourteen species of the Wilcox flora. These include two forms referred to *Calycites;* two to *Antholithus* and ten to *Carpolithus*. It would be quite useless to attempt any botanical discussion or comparison of these uncertain forms, such remarks as they suggest being more suitably confined to the discussion of the individual species.

JOHNS HOPKINS UNIVERSITY,
April 25, 1914.

SOLAR MAGNETIC PHENOMENA.[1]

By GEORGE E. HALE.

(*Read April 24, 1914.*)

The discovery by Stark of the electrical analogue of the Zeeman effect establishes a new point of view for the solar physicist. It is now known that an electric field, like a magnetic field, may cause the spectral lines of a light-source placed within it to break up into several components. Furthermore, these components, when observed at right angles to the lines of force, are plane polarized in both cases. Thus there are important points of resemblance between the Zeeman and Stark effects, and it becomes necessary to review the evidence on which the proof of the existence of solar magnetism is based. Is it possible that electric fields, rather than magnetic fields, are responsible for the observed spectroscopic phenomena?

Fortunately, as a brief consideration of the observations will show, this evidence is not open to the charge of ambiguity. The phenomena described in my papers on the magnetic fields of sun-spots and the general magnetic field of the sun are unmistakably those of the Zeeman effect. They are clearly ascribable, in their broad features, to magnetic rather than to electric fields, and if the latter exercise a secondary influence, it is not easily recognizable.

Here an important opportunity for further research is presented. The separation of electrons in sun-spots should give rise to electric fields, which may be sufficiently intense to produce an appreciable Stark effect. Other regions of the solar atmosphere where the conditions are most favorable for the production of electric fields are also open to investigation. But our knowledge of the spectroscopic

[1] Abstract. The complete details of the paper, which will be published in a series of articles in the *Astrophysical Journal*, include the results of investigations on the radial and tangential spot field; the rate of change of field-strength with level, both for spots and the general field; the relationship between field-strength and spot area; the complex fields of spot groups; the phenomena of bipolar spots, etc.

phenomena of all of these regions indicates that special methods of research will be required. It is true that the components of the hydrogen lines are much more widely separated by Stark's electric fields than by any magnetic fields yet produced. But electric fields sufficiently intense to produce such separation do not appear to exist in the sun.[2] Furthermore, when the observations can be made along the lines of force, it is easier to detect a magnetic field giving incomplete resolution of a line than an electric field causing equal overlapping of its constituent parts. This is because of the right-handed and left-handed polarization of the components: a characteristic feature which distinguishes the Zeeman effect from all other spectroscopic phenomena. The use of a quarter-wave plate in conjunction with a Nicol prism permits either component to be extinguished at will. Thus line displacements may be produced which are measurable with such precision as to disclose the existence of a magnetic field of only a few gausses. In fact, it might even be feasible, with special appliances, to detect the earth's field in this way. The absence of circular polarization prevents the observation of such displacements in the Stark effect, but the use of suitable apparatus may ultimately bring to light solar electric fields much weaker than those near the cathode of an ordinary vacuum tube. In any event, it will become possible to set an upper limit to the intensity of the electric fields existing in various parts of the sun.

Let us now review the evidence indicating the presence of magnetic fields in sun-spots, after recalling the hypothesis which led to the application of the tests for the Zeeman effect on Mount Wilson in 1908. This hypothesis, based on the forms and motions of the dark hydrogen ($H\alpha$) flocculi revealed a few weeks earlier with our five-foot spectroheliograph, holds that sun-spots are vortex phenomena. The electrons emitted at high solar temperatures, if whirled in a vortex, must produce a magnetic field, assuming the positive and negative electrons to be unequal in number. The recent work of Harker justifies the view that negative electrons would flow from the hot vapors surrounding the vortex toward the cooler

[2] Unless the widening of lines in the chromosphere, especially that associated with eruptive phenomena, where strong electric fields may be present, should prove to be due in part to their influence.

vapors within it, thus providing the separation called for in the hypothesis. As for the existence of the vortex, in a form different from that first assumed, it is abundantly confirmed by the discovery of Evershed, and the subsequent observations of Evershed and St. John on the motion of vapors in the solar atmosphere surrounding spots.

Assume the axis of the vortex to coincide approximately with a solar radius. Then, if the spot were central on the sun, the lines of force at its center would lie in the line of sight. Such an iron line as λ 6302.709, which is resolved by a magnetic field into three components, should then appear in the spot as a doublet, the central component being absent when observed along the lines of force. The two outer components should be circularly polarized in opposite directions, and it should be possible to extinguish either one at will with the aid of a Nicol prism and quarter-wave plate. Furthermore, two spot vortices rotating in opposite directions should show the opposite components of the line, with the same adjustment of the polarizing apparatus.

This test was successfully applied, and has since been repeated on many sun-spots. Under the most favorable conditions, either component can be completely extinguished. In general, however, the observations cannot be made exactly along the lines of force, and under such circumstances the elliptically polarized components are not completely cut off. Moreover, such a line as λ 6302.709 usually appears as a triplet, the relative intensities of the central and side components varying, as would be expected from the Zeeman effect, with the angle between the lines of force and the line of sight.

Speaking generally, this angle should increase as the spot approaches the sun's limb. We should therefore be able in this case to distinguish the phenomena of plane polarization, since in the laboratory the three components are plane polarized when observed normal to the lines of force. As the central component is polarized in a plane at right angles to the plane of polarization of the side components, it should be possible to extinguish this line in the spectrum of a spot near the limb by rotating the Nicol prism, used without quarter-wave plate. This experiment has been successfully performed.

I need not dwell here on the other evidences of the Zeeman effect, but the proof is very complete. The resolution of the spot lines is not sufficiently perfect to permit the numerous components shown in some cases by laboratory observations to be detected, but triplets and quadruplets can be distinguished, and the resemblance of the observed effects to those of a magnetic field is very close for all lines. One of the most important tests is afforded by the steady decrease in the average separation of the components toward the violet, corresponding with the fact that in a magnetic field their separation is proportional to the square of the wave-length. Here we have a marked disagreement with the Stark effect, where the separation of the components *increases* toward the violet.

In the case of the sun's general magnetic field, my conclusions are also based exclusively upon displacements due to circular or elliptical polarization. This field, which is about eighty times as intense as that of the earth, but of only about one hundredth of the intensity of the maximum sun-spot field, is quite insufficient to separate the solar lines. In fact, the widening which it produces is much too small to be detected, and it is only through the possibility of cutting off one or the other component, and thus of producing a slight shift, that it can be measured.

In the Stark effect the absence of circular or elliptical polarization compels us to seek for evidence presented by changes in the width of lines. The hydrogen lines $H\beta$ and $H\gamma$, when observed for the transverse effect, have been shown by Stark to have five components, the three inner polarized at right angles, the two outer parallel to the field. In the longitudinal effect the two outer components are absent, while the three inner components are present but unpolarized. In the general electric field of the sun the lines of force may be regarded as radial. Hence all lines having Stark effects similar to those of the hydrogen lines should be wider near the limb than at the center of the sun, and their plane polarized outer edges should be capable of extinction by a Nicol. Lack of symmetry in the distribution of the components of a line, such as Stark has observed in some cases, would cause a shift of the lines near the limit. Tests made some time ago, in connection with the study of the

Zaeman effect, indicate that the well-known widening and displacement of the solar lines near the limb are not due primarily to this cause, though there may prove to be a second order effect smaller than I have yet been able to recognize.

A compound half-wave plate, made of narrow strips of half-wave mica, so mounted that (when used with a Nicol) the alternate strips will transmit light polarized in planes at right angles to one another, is to be strongly recommended for this purpose. This will permit the widths and the positions of the solar lines to be compared on a single photograph, in the way which has proved so advantageous in the study of the sun's general magnetic field.[8]

In a preliminary study of our photographs of sun-spot spectra, some of which were taken with the Nicol alone, I have been unable to detect any promising evidence of the Stark effect. However, these plates are poorly adapted for the purpose, and the investigation will soon be continued, and extended to various parts of the solar atmosphere.

[8] Contributions from the Mount Wilson Solar Observatory, No. 71.

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THE VEGETATION OF THE SARGASSO SEA.

BY WILLIAM G. FARLOW, PH.D., LL.D.

(*Read April 24, 1914.*)

On September 16, 1492, Columbus encountered masses of floating seaweed in latitude 28° N. 58° W. as he was approaching the Bahama Islands. This is the first record of the existence of what is now known as the Sargasso Sea. Since that date many navigators and travellers, who have traversed that region, have described the general appearance of the sea and have attempted to ascertain its limits and to explain the source from which the floating gulf-weed was derived. Unfortunately, however, the earlier accounts were often rather vague and to some extent conflicting and even well-known scientific men, as Humboldt, have been too much inclined to call attention to the sea as one of the wonders of nature rather than to attempt to record the facts about it accurately. Humboldt, for instance, described the Sargasso Sea as an area six times as large as Germany covered with a growth of a single species of seaweed which he regarded as very remarkable considering the small size of the land areas covered by the growth of a single species of plant. Although Humboldt's account is in a sense true, the impression that those who read his account receive is misleading.

The account given by Alexander Agassiz in 1888 was less sensational. He says:

"The Sargasso Sea of the North Atlantic covers a rather indefinite area between 22° and 36° N. and according to the statements of the older navigators, the amount of Sargassum to be met with varies from occasional patches to masses large enough to impede the progress of sailing vessels. The Sargassum probably changes its position constantly, according to the seasons, the currents, and the direction of the wind; but within the area bounded by the Gulf Stream on the West, the equatorial current on the South and the return current from the Azores and Canaries the Sargassum has always been found in larger or smaller quantities."

At the present day we have a definite knowledge of the ocean currents and the prevailing winds of the Atlantic which are important factors in the distribution of the gulf-weed. My personal experience, which has been confined to that part of the Ocean lying between New York and Bermuda, agrees with that of most recent travellers who have traversed the Sargasso Sea in various directions and it may be said that the gulf-weed occurs in scattered patches which are usually from fifty to, at the most, a few hundred feet in diameter. It appears to be certain that in no place is the Sea covered by the gulf-weed in continuous masses miles in extent and it is not often the case that the patches extend over a space as large as an acre. Their long diameter is usually in the direction of the wind and their frequency varies very much according to circumstances. Whether they are ever so dense as actually to impede modern sailing vessels seems to me doubtful, and it must be said that those who make the statement that the progress of vessels may be impeded by the gulf-weed usually preface their remarks by saying 'according to older navigators' and do not depend on their own observations.

If at the present day we have a good topographical knowledge of the Sargasso Sea, the question as to the particular species to which the gulf-weed belongs still presents several perplexing problems and, as to the origin of the gulf-weed, as recently as 1907 Sauvageau wrote: "les causes de sa formation ne sont guère mieux connues que lors du premier voyage de Christophe Colomb." Sargassum, to which the gulf-weed, *Sargassum bacciferum*,[1] belongs is

[1] The name *Sargassum bacciferum* is used here since it has been the name most commonly used to designate the gulf-weed. Boergesen in his paper, "The species of *Sargassum* found along the coasts of the Danish West Indies with Remarks upon the Floating Forms of the Sargasso Sea," Copenhagen, 1914, states fully the reasons for preferring the name *Sargassum natans* (L.) on the ground of priority.

a large genus, the largest of all the genera of the larger brown seaweeds, and includes mainly species which inhabit the tropics, or more accurately between about 42° N. and 42° S. latitude. They flourish just below low water mark but do not grow in deep water. They are attached to the substratum by a hold-fast and grow not infrequently to be three feet long, with a branching, slender stem bearing leaves with small, stalked air-bladders near their bases. The fruit, the spores, are in cavities on special branches. The genus is a difficult one for the systematic botanist because, to be sure of a species, one should have not only the stem with its leaves but also the base and the fruit and in many cases species have been described from fragments only. Furthermore the individuals of most species vary very much so that, without a study of a set of living specimens, an algologist might be pardoned for believing that he had not one but several species before him, judging by herbarium specimens only. The points I have just mentioned must be borne in mind in what I have to say about the gulf-weed. It remains for us to consider the two questions: What is the gulf-weed and where does it come from?

All observations agree that the masses of floating gulf-weed consist in far the greater part of the single species, called *Sargassum bacciferum.* If, however, we examine more closely the traditional gulf-weed we find that although it has the characteristic leaves and bladders of the genus, it has no remains of a basal attachment and no fruit except in certain very rare and not well authenticated cases. Some believing that, if not impossible, it is certainly very improbable that any species could continue to flourish indefinitely like the gulf-weed without at some time fruiting and, furthermore, seeing a certain resemblance of the leaves and bladders to those of certain species of Sargassum growing attached in the West Indies and on the Florida coast, have advanced the opinion that the floating form called gulf-weed consists of branches broken from the attached forms and carried by the gulf stream to the different parts of the Sargasso Sea. Others maintain that this is not the only case of a plant living and flourishing without producing fruit, and that, since up to the present time, no one has found the *Sargassum bacciferum* attached and fruiting, we are forced to believe that it is a distinct but always sterile species and not a form of any other attached

species. This latter opinion is the one held by most recent writers.

The question is not as simple as it seems at first sight. It may be asked whether *Sargassum bacciferum* occurs in other places than the Sargasso Sea and its immediate vicinity. What has been considered to be this species has been reported to occur in New Zealand, Australia, Java and various places in the Pacific and Indian Oceans as well as Valparaiso but only scattered specimens have been found and there is no evidence whatever that there is more than one Sargasso Sea in the world and it may be questioned whether all the specimens supposed to be *S. bacciferum* from other regions are really the same as the Atlantic form. I have a specimen marked New Zealand which seems to be the real gulf-weed but the data on the label are scanty and I do not feel sure that the locality is correctly given. Von Marten's theory that the gulf-weed originated in the Indian Ocean and was carried by currents round the Cape of Good Hope to the Sargasso Sea has nothing to support it, nor can the theory of Ed. Forbes that the floating gulf-weed is the survival of Sargassum growing on the submerged Atlantis be seriously considered.

As a waif, or straggler, the gulf-weed is occasionally deposited on the shores of northwestern Europe but in Great Britain, at least, it must be very rare for in his Phycologia Britannica Harvey was obliged to draw his figure of *L. bacciferum* from an American, not a British specimen. On the east American coast specimens of the gulf-weed are very rare. The only specimen which I have is a fragment washed ashore at Bath, Long Island. Some years ago I was told by a sea captain that there was a bank of gulf-weed off Nantucket but I have been unable to obtain any confirmation of this statement. Even if there is such a bank, the chances are that it is composed of *S. filipendula,* which is very abundant on the adjacent shore of Cape Cod.

As has been said, by far the greater part of the gulf-weed masses is composed of *S. bacciferum.* That it is exclusively so is not true. Agardh states that *S. Hystrix* is found with *S. bacciferum* and recently Boergesen has reported the same species near the Danish West Indies; *S. vulgare,* a very common attached species of the West Indies has also been found with the gulf-weed. The mixture

of the two species does not appear to be common in the Sargasso Sea itself but, as one approaches the land, the floating *S. vulgare* mixed with *S. bacciferum* is common and one finds both common even on the surface of landlocked waters like Harrington Sound, Bermuda.

A very interesting case is that of the mixture of a species of Cystoseira and gulf-weed collected by Professor F. H. Storer on a voyage from the Cape of Good Hope to New York. The exact position cannot be stated but according to information given by Professor Storer it was approximately 10° N. by 40° to 45° W. One gathering only was made and from it was obtained the specimens of *S. bacciferum* distributed in the "Algæ Americæ Borealis" of Farlow, Anderson and Eaton. This set has been seen by all the well known algologists of the world and, as no one has questioned the determination, it may be supposed to be correct. The Cystoseira was entangled in the Sargassum. The species of Cystoseira are complicated and not easy to name and the specimens in question were not in fruit. As far as I could tell, the species appeared to be very near *C. crinita* Bory, a Mediterranean species. Specimens have been examined by Sauvageau, the expert student of the genus, whose opinion is that in spite of certain points in common with *C. crinita* he would not venture to assert that they belong to that species. The interesting fact, however, is that, whether *C. crinita* or not, it must have come from the southeastern shore of Europe or of Northern Africa including the Atlantic islands since the species of Cystoseira abound in that region and, with one exception, none are found on the east coast of North America. *C. Myrica* is a rare species of Florida and the Bahamas and is quite different from the floating Cystoseira. As far as could be told from the material collected by Professor Storer, the Cystoseira in spite of its long journey was in as good a condition as the gulf-weed with which it was found. This is instructive as showing how far specimens can be transported by currents without perceptible injury.

In conclusion, in the limited time at our disposal, I shall show you a few slides of the gulf-weed and related species to illustrate more clearly some of the points I have mentioned. Everything considered it seems to me that in the present state of our knowledge we

are not as yet warranted in assuming that the floating gulf-weed could not have been derived originally from some fixed, fruiting form. Certainly we do not at present know from what species it might have been derived but, until the distribution of the Sargassa on the eastern coast of America and the West Indies is better known and the characteristics and variations of the various described species have been more thoroughly studied, the question of the origin of the gulf-weed seems to me to be still open.

THE KINETIC SYSTEM.

By GEORGE W. CRILE, M.D.

(Read April 22, 1914.)

In this paper I formulate a theory which I hope will harmonize a large number of clinical and experimental data, supply an interpretation of certain diseases, and show by what means many diverse causes produce the same end effects.

Even should the theory prove ultimately to be true, it will meantime doubtless be subjected to many alterations. The specialized laboratory worker will at first fail to see the broader clinical view, and the trained clinician may hesitate to accept the laboratory findings. Our viewpoint has been gained from a consideration of both lines of evidence on rather a large scale.

The responsibility for the kinetic theory is assumed by myself, while the responsibility for the experimental data is shared fully by my associates, Dr. J. B. Austin, Dr. F. W. Hitchings, Dr. H. G. Sloan and Dr. M. L. Menten.

Introduction.

The self-preservation of man and kindred animals is affected through mechanisms which transform latent energy into kinetic energy to accomplish adaptive ends. Man appropriates from environment the energy he requires in the form of crude food which is refined by the digestive system; oxygen is taken to the blood and carbon dioxid is taken from the blood by the respiratory system; to and from the myriads of working cells of the body, food and oxygen and waste are carried by the circulatory system; the body is cleared of waste by the urinary system; procreation is accomplished through the genital system; but none of these systems are evolved primarily for the purpose of transforming potential energy into kinetic energy for specific ends. Each system transforms such amounts of potential into kinetic energy as are required to perform its specific work; but no one of them transforms latent into kinetic energy for the

purposes of escaping, of fighting, of pursuing; or for combating infection. The stomach, the kidneys, the lungs, the heart strike no physical blow—their rôle is to do certain work to the end that the blow may be struck by another system evolved for that purpose. I propose to offer evidence that there is in the body a system evolved primarily for the transformation of latent energy into motion and into heat. This system I propose to designate the Kinetic System.

The kinetic system does not directly circulate the blood, nor does it exchange oxygen and carbon dioxid; nor does it perform the functions of digestion, urinary elimination and procreation; but though the kinetic system does not directly perform these functions, it does play indirectly an important rôle in each, just as the kinetic system itself is aided indirectly by the other systems.

The principal organs which comprise the kinetic system are the brain, the thyroid, the suprarenals, the liver and the muscles. The brain is the great central battery which drives the body; the thyroid governs the conditions favoring tissue oxidation; the suprarenals govern immediate oxidation processes; the liver fabricates and stores glycogen; and the muscles are the great converters of latent energy into heat and motion.

Adrenalin alone, thyroid extract alone, brain activity alone, and muscular activity alone are capable of causing the body temperature to rise above the normal. The functional activity of no other gland of the body alone, and the secretion of no other gland alone can cause a comparable rise in body temperature—that is, increased functional activity; and no active principle derived from the kidney, the liver, the stomach, the pancreas, the hypophysis, the parathyroid, the spleen, the intestines, the thymus, the lymphatic glands or the bones can, *per se,* cause a rise in the general body temperature comparable to the rise that may be caused by the activity of the brain or the muscles, or by the injection of adrenalin or thyroid extract. Then, too, when the brain, the thyroid, the suprarenals, the liver or the muscles are eliminated, the power of the body to convert latent into kinetic energy is impaired or lost. I shall offer evidence tending to show that an excess of either internal or external environmental stimuli may modify one or more organs of the kinetic system, and that this modification may cause certain diseases. For example,—

alterations in the efficiency of the cerebral link may yield neurasthenia, mania, dementia; of the thyroid link,—Graves' disease, myxedema; of the suprarenal link,—Addison's disease, cardiovascular disease.

This introduction may serve to give the line of our argument. We shall now consider briefly certain salient facts which relate to the conversion of latent energy into kinetic energy as an adaptive reaction. The amount of experimental data is so large that they will later be published in a monograph.

The amount of latent energy which may be converted into kinetic energy for adaptive ends varies in different species, in individuals of the same species, in the same individual in different seasons; in the life cycle of growth, reproduction and decay; in the waking and sleeping hours; in disease and in activity. We shall here consider briefly the reasons for some of those variations and the mechanism which makes them possible.

Biologic Consideration of the Adaptive Variation in Amounts of Energy Stored in Various Animals.

Energy is appropriated from the physical forces of nature that constitute the environment. This energy is stored in the body in quantities in excess of the needs of the moment. In some animals this excess storage is greater than in other animals. Those animals whose self-preservation is dependent on purely mechanical or chemical means of defense, such animals as crustaceans, porcupines, skunks or cobras, have a relatively small amount of convertible (adaptive) energy stored in their bodies. On the contrary, the more an animal is dependent on its muscular activity for self-preservation the more surplus available (adaptive) energy there is stored in its body. It may be true that all animals have approximately an equal amount per kilo of chemical energy—but certainly they have not an equal amount stored in a form which is available for immediate conversion for adaptive ends.

Adaptive Variation in the Rate of Energy Discharge.

What chance for survival would a skunk have without odor; a cobra without venom; a turtle without carapace; or a porcupine

shorn of its barbs, in an environment of powerful and hostile carnivora? And yet in such a hostile environment many unprotected animals survive by their muscular power of flight alone. It is evident that the provision for the storage of "adaptive" energy is not the only evolved characteristic which relates to the energy of the body. The more the self-preservation of the animal depends on motor activity, the greater is the range of variation in the rate of discharge of energy. The rate of energy discharge is especially high in animals evolved along the line of hunter and hunted, such as the carnivora and the herbivora of the great plains.

Influences That Cause Variation in the Rate of Output of Energy in the Individual.

Not only is there a variation in the rate of output of energy among various species of animals, but one finds also variations in the rate of output of energy among individuals of the same species. If our thesis that men and animals are mechanisms responding to environmental stimuli is correct, and further, if the speed of energy output is due to changes in the activating organs as a result of adaptive stimulation, then we should expect to find physical changes in the activating glands during the cycles of increased activation. What are the facts? We know that most animals have breeding seasons evolved as adaptations to the food supply and weather. Hence there is in most animals a mating season in advance of the season of maximum food supply so that the young may appear at the period when food is most abundant. In the springtime most birds and mammals mate, and in the springtime at least one of the great activating glands is enlarged—the thyroid in animals and in man shows seasonal enlargement. The effect of the increased activity is seen in the song, the courting, the fighting, in the quickened pulse and in a slightly raised temperature. Even more activation than that connected with the season is seen in the physical act of mating—when the thyroid is known to enlarge materially, though this increased thyroid activity, as we shall show later, is probably no greater than the increased activity of other activating glands. In the mating season the kinetic activity is speeded up; in short, there exists a state—a fleeting state—of mild Graves' disease; in the early stages of Graves' disease, before

the destructive phenomena are felt, the kinetic speed is high and life is on a sensuous edge. Not only is there a seasonal rhythm to the rate of flow of energy, but there is a diurnal variation, the ebb is at night, and the full tide in the daytime. This observation is verified by experiments which show that certain organs in the kinetic chain are histologically exhausted, the depleted cells being for the most part restored by sleep.

We have seen that there are variations in speed in different species, and that in the same species speed varies with the season of the year and with the time of day. In addition there are variations also in the rate of discharge of energy in the various cycles of the life of the individual. The young are evolved at high speed for growth, so that as soon as possible they may attain to their own power of self-defense; they must adapt themselves to innumerable bacteria; to food, and to all the elements in their external environment. Against their gross enemies the young are measurably protected by their parents; but the parents—except to a limited extent in the case of man—are unable to assist in the protection of the young against infectious disease.

The cycle of greatest kinetic energy for physiologic ends is the period of reproduction. In the female especially there is a cycle of increased activity just prior to her development into the procreative state. During this time secondary sexual characters are developed—the pelvis expands, the ovaries and the uterus grow rapidly, the mammary glands develop. Again in this period of increasing speed in the expenditure of energy we find the thyroid, the suprarenal and the hypophysis also in rapid growth. Without the normal development of the ovary, the thyroid and the hypophysis, neither the male nor the female can develop the secondary sexual characters, nor do they develop sexual desire nor show seasonal cycles of activity, nor can they procreate. The secondary sexual characters—sexual desire, fertility—may be developed at will—for example, by feeding thyroid products from alien species to the individual deprived of the thyroid.

At the close of the childbearing period there is a permanent diminution of the speed of energy discharge, for energy is no longer needed as it was for the self-preservation of the offspring before

adolescence, and for the propagation of the species during the procreative period. Unless other factors intervene this reduction in speed is progressive until senescent death. The diminished size of the thyroid of the aged bears testimony to the part the activating organs bear in the general decline.

We have now referred to variations in the rate of discharge of energy in different species; in individuals of the same species; in cycles in the same individual—such as the seasons of food supply; the periods of wakefulness and of sleep; the procreative period—and we have spoken of those variations caused artificially by thyroid feeding.

Thus far we have referred to the conversion for adaptive purposes of latent into kinetic energy in muscular and in procreative action. We shall now consider the conversion of latent into kinetic energy in the production of heat,[1] and endeavor to answer the questions which arise at once:—Is there one mechanism for the conversion of latent energy into heat and another mechanism for its conversion into muscular action? What is the adaptive advantage of fever in infection?

The Purpose and the Mechanism of Heat Production in Infections.

Vaughn has shown that the presence in the body of any alien protein causes an increased production of heat, and that there is no difference between the production of fever by foreign protein and by infections. Before the day of the hypodermic needle and of experimental medicine, the foreign proteins found in the body outside the alimentary tract were brought in by invading microörganisms. Such organisms interfered with and destroyed the host. The body, therefore, was forced to evolve a means of protection against these hostile organisms. The increased metabolism and fever in infection might operate as a protection in two ways: the increased fever by interfering with bacterial growth, and the increased metabolism by breaking up the bacteria. Bacteriologists have taught us that bacteria grow best at the normal temperature of the body, hence fever

[1] We use the terms heat and muscular action in the popular sense, though physicists use them to designate one and the same kind of energy.

would interfere with bacterial growth. With each rise of one degree centigrade the chemical activity of the body is increased ten per cent. In acute infections there is aversion to food and frequently there is vomiting. In fever, then, we have a diminished intake of energy, but an increased output of energy—hence the available potential energy in the body is rapidly consumed. This may be an adaptation for the purpose of breaking up the foreign protein molecules composing the bacteria. Thus the body may be purified by a chemical combustion so furious that frequently the host itself is destroyed. The problem of immunity is not considered here.

As to the mechanism which produces fever, we postulate that it is the same mechanism as that which produces muscular activity. Muscular activity is produced by the conversion of latent energy into motion, and fever is produced largely in the muscles by the conversion of latent energy into heat. We should, therefore, find similar changes in the brain, the suprarenals, the thyroid, and the liver, whatever may be the purpose of the conversion of energy—whether for running, for fighting, for the expression of emotion, or for combating infection.

We shall first present experimental and clinical evidence which tends to show what part is played by the brain in the production of both muscular and febrile action, and later we shall discuss the parts played by the suprarenals, the thyroid, and the liver.

Histologic Changes in the Brain-Cells in Relation to the Maintenance of Consciousness and to the Production of the Emotions, Muscular Activity and Fever.

We have studied the brain-cells in human cases of fever, and in animals after prolonged insomnia; after the injection of the toxins of gonococci, of streptococci, of staphylococci, and of colon, tetanus, diphtheria and typhoid bacilli; and after the injection of foreign proteins, of indol and skatol, of leucin and of peptones. We have studied the brains of animals which had been activated in varying degrees up to the point of complete exhaustion by running, by fighting, by rage and fear, by physical injury and by the injection of strychnia. We have studied the brains of salmon at the mouth of the Columbia River and at its headwater; the brains of electric fish,

the storage batteries of which had been partially discharged, and of those the batteries of which had been completely discharged; the brains of woodchucks in hibernation and after fighting; the brains of humans who had died from anemia resulting from hemorrhage, from acidosis, from eclampsia, from cancer, and from other chronic diseases. We have studied also the brains of animals after the excision of the suprarenals, of the pancreas, and of the liver.

In every instance the loss of vitality—that is, the loss of the normal power to convert potential into kinetic energy—was accompanied by physical changes in the brain-cells. The converse was also true—that is, the brain-cells of animals with normal vital power showed no histologic changes. The changes in the brain-cells were identical whatever the cause. The crucial question then becomes: Are these constant changes in the brain-cells the result of work done by the brain-cells in running, in fighting, in emotion, in fever? In other words, does the brain perform a definite rôle in the conversion of latent energy into fever or into muscular action; or are the brain-cell changes caused by the chemical products of metabolism? Happily this crucial question was definitely answered by the following experiment: The circulations of two dogs were crossed in such a manner that the circulation of the head of one dog was anastomosed with the circulation of the body of another dog and vice versa. A cord encircled the neck of each so firmly that the anastomosing circulation was blocked. If the brain-cell changes were due to the metabolic products, then when the body of dog "A" was injured, the brain of dog "A" would be normal and the brain of dog "B" would show changes. Our experiments showed brain-cell changes in the brain of the dog injured and no changes in the brain of the uninjured dog.

The injection of adrenalin causes striking brain-cell changes—first, a hyperchromatism, then a chromatolysis. Now if adrenalin caused these changes merely as a metabolic phenomenon and not as a "work" phenomenon, then the injection of adrenalin into the carotid artery of a crossed circulation dog would cause no change in its circulation and its respiration, since the brain thus injected is in exclusive vascular connection with the body of another dog. In our experiment the blood-pressures of both dogs were recorded on a drum when adrenalin was injected into the common carotid. The adre-

nalin caused a rise in blood-pressure, an increase in the force of cardiac contraction, increase in respiration, and a characteristic adrenalin rise in the blood-pressure of both dogs. The rise was seen first in the dog whose brain alone received adrenalin and about a minute later in the dog whose body alone received adrenalin. Histologic examinations of the brains of both dogs showed marked hyperchromatism in the brain receiving adrenalin, while the brain receiving no adrenalin showed no change. Here is a clear-cut observation on the action of adrenalin on the brain—and both the functional and the histological tests showed that adrenalin causes increased brain action. The significance of this affinity of the brain for adrenalin begins to be seen when I call attention to the following striking facts:

1. Adrenalin alone causes hyperchromatism followed by chromatolysis, and in overdosage causes the destruction of some brain-cells.

2. When the suprarenal glands are both excised and no other factor is introduced, the Nissl substance progressively disappears from the brain-cells until death. This far-reaching point will be taken up later.

Here our purpose is to discuss the cause of the brain-cell changes. We have seen that in crossed brain and body circulation trauma cause changes in the cells of the brain which is disconnected from the traumatized body by its circulation, but which is connected with the traumatized body by the nervous system. We have seen that adrenalin causes activation of the body connected with its brain by the nervous system, and histologic changes in the brain acted on directly by the adrenalin, but we found no brain-cell changes in the other brain through which the products of metabolism have circulated.

In the foregoing we find direct evidence that the brain-cell changes are not due to the products of metabolism. We shall now present evidence to show that the brain-cell changes are "work" changes. What work? We postulate that it is the work by which the energy stored in the brain-cells is converted into electricity or some other form of transmissible energy which then activates certain glands and muscles, thus converting latent energy into heat and motion. It has chanced that certain other studies have given an analogous and convincing proof of this postulate. In the electric fish a part of the muscular mechanism is replaced by a specialized structure for storing

and discharging electricity. We found "work" changes in the brain-cells of electric fish after all their electricity had been rapidly discharged. We found further that electric fish could not discharge their electricity when under anesthesia, and clinically we know that under deep morphia narcosis, and under anesthesia, the production both of heat and of muscular action is hindered. The action of morphia in lessening fever production is probably the result of its depressing influence on the brain-cells, because of which a diminished amount of their potential energy is converted into electricity and a diminished electric discharge from the brain to the muscles should diminish heat production proportionally. We found by experiment that under deep morphinization brain-cell changes due to toxins could be largely prevented; in human patients deep morphinization diminishes the production of muscular action and of fever, and as we shall see later conserves life when it is threatened by acute infections. The contribution of the brain-cells to the production of heat is either the result of the direct conversion of their stored energy into heat, or of the conversion of their latent energy into electricity or a similar force, which in turn causes certain glands and muscles to convert latent energy into heat.

A further support to the postulate that the brain-cells contribute to the production of fever by sending impulses to the muscles is found in the effect of muscular exertion, or of other forms of motor stimulation in the presence of a fever-producing infection. Under such circumstances muscular exertion causes additional fever, and causes also added but identical changes in the brain-cells. Thyroid extract and iodin have the same effect as muscular exertion and infection in the production of fever and the production of brain-cell changes. All of this evidence is a strong argument in favor of the theory that certain constituents of the brain-cells are consumed in the work performed by the brain in the production of fever.

That the stimulation of the brain-cells without gross activity of the skeletal muscles and without infection can produce heat is shown as follows:

(*a*) Fever is produced when animals are subjected to fear without any consequent exertion of the skeletal muscles.

(*b*) The temperature of the anxious friends of patients will rise while they await the outcome of an operation.

(*c*) The temperature of patients will rise as a result of the mere anticipation of a surgical operation.

(*d*) There are innumerable clinical observations as to the effect of emotional excitation on the temperature of patients. A rise of a degree or more is a common result of a visit from a tactless friend. There is a traditional Sunday increase of temperature in hospital wards. Now the visitor does not bring and administer more infection to the patient to cause this rise, and the rise of temperature occurs even if the patient does not make the least muscular exertion as a result of the visit. I observed an average increase of one and one eighth degrees of temperature in a ward of fifteen children as a result of a Fourth of July celebration.

Is the contribution of the brain to the production of heat due to the conversion of latent energy directly into heat, or does the brain produce heat principally by converting its latent energy into electricity or some similar form of transmissible energy which through nerve connections stimulates other organs and tissues, which in turn convert their stores of latent energy into heat?

According to Starling, when the connection between the brain and the muscles of an animal is severed by curare, by anesthetics, by the division of the cord and nerves, then the heat-producing power of the animal so modified is on a level with that of cold-blooded animals. With cold the temperature falls, with heat it rises. Such an animal has no more control over the conversion of latent energy into heat than it has over the conversion of latent energy into motion.

Electric stimulation done over a period of time causes brain-cell changes, and electric stimulation of muscles causes a rise in temperature.

Summary.

In our crossed circulation experiments we found that the brain-cell changes were not due to waste products or to metabolic poisons. We found that in the production both of muscular action and of fever there were brain-cell changes which showed a quantitative relation to the temperature changes or to the muscular

work done. We observed that under deep morphinization the febrile response or the muscular work done was either diminished or eliminated and that the brain-cell changes were correspondingly diminished or eliminated. We found also that brain-cell changes and muscular work followed electric stimulation alone. I conclude, therefore, that the brain-cell changes are work changes.

We shall next consider other organs of the kinetic system in their relation to muscular activity, to emotion, to consciousness, to sleep, to hibernation, and to heat production.

The Suprarenal Gland.

In our extensive study of the brain in its relation to the production of energy and consequent exhaustion caused by fear and rage; by the injection of foreign proteins, of bacterial toxins and of strychnin; by anaphylaxis; by the injection of thyroid extract, of adrenalin, and of morphin; we found that with the exception of morphin each of these agents produced identical changes in the brain-cells. As we believed that the suprarenal glands were intimately associated with the brain in its activities, we concluded that the suprarenals also must have been affected by each of these agents. To prove this relation, we administered the above-mentioned stimuli to animals and studied their effects upon the suprarenal glands by functional, histological and surgical methods, the functional tests being made by Cannon's method.

Functional Study of the Suprarenal Glands by Cannon's Method.

Our method of applying the Cannon test for adrenalin was as follows: (*a*) The blood of the animal's was tested before the application of the stimulus. If this test was negative, then (*b*) the stimulus was applied and the blood again tested. If this test was negative, a small amount of adrenalin was added. If a positive reaction was then given, the negative result was accepted as conclusive. (*c*) If the control test was negative, then the stimulus was given. If the blood after stimulation gave a positive result for adrenalin, a second test of the same animal's blood was made twenty-five minutes or

more later. If the second test was negative, then the positive result of the first test was accepted as conclusive.

We have recorded sixty-six clear-cut experiments on dogs, which show that after fear and rage, after anaphylaxis, after injections of indol and skatol, of leucin and tyrosin, of the toxins of diphtheria and colon bacilli, of streptococci, and staphylococci, of foreign proteins and of strychnin, the Cannon test for adrenalin was positive. The test was negative after trauma under anesthesia, and after intravenous injections of thyroid extract, of thyroglobin and of the juices of various organs injected into the same animal from which the organs were taken. Placental extract gave a positive test. The test was sometimes positive after electric stimulation of the splanchnic nerves. On the other hand, if the nerve supply to the suprarenals had been previously divided, or if the suprarenals had been previously excised, then the Cannon test was negative, after the administration of each of the foregoing adequate stimuli. Blood taken directly from the suprarenal vein gave a positive result, but under deep morphinization the blood from the suprarenal vein was negative, and under deep morphinization the foregoing adequate stimuli were negative.

In brief, the agencies that in our brain-cell studies were found to cause hyperchromatism followed by chromatolysis, gave positive results in the Cannon test for adrenalin. The one agent which was found to protect the brain against changes in the Nissl substance—morphin—gave a negative result in the Cannon test for adrenalin. After excision of the suprarenals, or after division of their nerve supply, all Cannon tests for adrenalin were negative.

Histologic Studies of the Suprarenal Glands.

Histologic studies of the suprarenal glands after the application of the adequate stimuli which gave positive results to the Cannon tests for adrenalin are now in progress and thus far the histologic studies corroborate the functional tests.

In hibernating woodchucks, the cells of the adrenal cortex were found to be vacuolated, and shrunken. In 100 hours of insomnia, in surgical shock, in strong fear, in exhaustion from fighting, in peptone injections, in acute infections, the suprarenal glands undergo

histological changes characteristic of exhaustion. Alkalies cause suprarenal changes, but acids do not.

We have shown that brain and suprarenal activity go hand in hand—that is, that the suprarenal secretion activates the brain, and that the brain activates the suprarenals. The fundamental question which now arises is this: Are the brain and the suprarenals interdependent? A positive answer may be given to this question, for the evidence of the dependence of the brain upon the suprarenals is as clear as is the evidence of the dependence of the suprarenals upon the brain. (1) After excision of the suprarenals, the brain-cells undergo continuous histological and functional deterioration until death. During this time the brain progressively loses its power to respond to stimuli and there is also a progressive loss of muscular power and a diminution of body temperature. (2) In our crossed circulation experiments we found that adrenalin alone could cause increased brain activity, while histologically we know that adrenalin alone causes an increase of the Nissl substance. An animal both of whose suprarenals had been excised showed no hyperchromatism in the brain-cells after the injection of strychnin, of toxins, of foreign proteins, etc. (3) When the suprarenal nerve supply was divided (Cannon-Elliott), then there was no increased suprarenal activity in response to adequate stimuli.

From these studies we are forced to conclude not only that the brain and suprarenals are interdependent, but that the brain is actually more dependent upon the suprarenals than the suprarenals upon the brain, since the brain deteriorates progressively to death without the suprarenals, while the suprarenals whose connection with the brain has been broken by the division of their nerve supply will still produce sufficient adrenalin to support life.

From the strong affinity of the brain-cells for adrenalin which was manifested in our experiments, we may strongly suspect that the Nissl substance is a volatile, extremely unstable combination of certain elements of the brain-cells and adrenalin because the suprarenal glands alone do not take the Nissl stain and the brain deprived of adrenalin does not take Nissl stain. The consumption of the Nissl substance in the brain-cells is lessened or prevented by morphin as is the output of adrenalin; and the consumption of the Nissl substance

is also lessened or prevented by nitrous oxid. But morphin does not prevent the action of adrenalin injected into the circulation, hence the control of morphin over energy expenditure is exerted directly on the brain-cells. Apparently morphin and nitrous oxid both act through this interference with oxidation in the brain. We, therefore, conclude that within a certain range of acidity of the blood adrenalin can unite with the brain-cells only through the mediation of oxygen, and that the combination of adrenalin, oxygen, and certain brain-cell constituents causes the electric discharge that produces heat and motion. In this interrelation of the brain and the suprarenals, we have what is perhaps the master key to the automatic action of the body. Through the special senses environmental stimuli reach the brain and cause it to liberate energy which in turn activates certain other organs and tissues, among which are the suprarenal glands. The increased output of adrenalin activates the brain to still greater activity, as a result of which again the entire sympathetic nervous system is further activated, as is manifested by increased heart action, more rapid respiration, raised blood-pressure, increased output of glycogen, increased power of the muscles to metabolize glucose, etc.

If this conclusion is well founded, we should find corroborative evidence in histologic changes in that great store-house of potential energy, the liver, as a result of the application of each of the adequate stimuli which produced brain-cell and suprarenal changes.

The Liver.

Prolonged insomnia, prolonged physical exertion, infections, injections of toxins, and of strychnin, rage and fear, physical injury under anesthesia, in fact all of the adequate stimuli which affected the brain and the suprarenals, produced constant and identical histologic changes in the liver—the cells stained poorly, the cytoplasm was vacuolated, the nuclei were crenated, the cell membranes were irregular, the most marked changes occurring in the cells of the periphery of the lobules. In prolonged insomnia the striking changes in the liver were repaired by one seance of sleep.

Are the histologic changes in the liver cells due to metabolism or toxic products or are they "work" changes incident to the conversion of latent into kinetic energy? Are the brain, suprarenals and liver

interdependent? The following facts establish the answers to these queries:

1. The duration of life after excision of the liver is about the same as after adrenalectomy—approximately eighteen hours.

2. The amount of glycogen in the liver was diminished in all of the experiments showing brain-suprarenal activity; and when the histologic changes were repaired, the normal amount of glycogen was again found.

3. In crossed circulation experiments changes were found in the liver of the animal whose brain received the stimulus.

From these premises we must consider that the brain, the suprarenals, and the liver are mutually dependent on each other for the conversion of latent into kinetic energy. Each is a vital organ—each equally vital. It may be said that excision of the brain may apparently cause death in less time than excision of the liver or suprarenals, but this statement must be modified by our definition of death. If all the brain of an animal be removed by decapitation, its body may live on for at least eleven hours if its circulation be maintained by transfusion. An animal may live for weeks or months after excision of the cerebral hemispheres and the cerebellum, while an over-transfused animal may live many hours, for days, even after the destruction of the medulla. It is possible even that the brain actually is a less vital organ than either the suprarenals or the liver.

In our research to discover whether any other organs should be included with the brain, the suprarenals and the liver in this mutually interdependent relation, we hit upon an experiment which throws light upon this problem.

Groups of rabbits were gently kept awake for 100 hours by relays of students,—an experiment which steadily withdrew energy but caused not the slightest physical or emotional injury to any of them; no drug, toxin, or other agent was given to them; they were given sufficient food and drink. In brief, the internal and external environments of these animals were kept otherwise normal excepting for the gentle stimuli which ensured continued wakefulness. This protracted insomnia gradually exhausted the animals completely, some to the point of death even. Some of the survivors were killed im-

mediately after the expiration of 100 hours of wakefulness, others after varying intervals.

Histological studies were made of every tissue and organ in the body. Three organs, the brain, the suprarenals, and the liver, and these three only showed histologic changes. In these three organs the histologic changes were marked, and were almost wholly repaired by one seance of sleep. In each instance these histologic changes were identical with those seen after physical exertion, emotions, toxins, etc. It would appear, then, that these three organs take the stress of life—the brain is the battery, the suprarenals the oxidizer, and the liver the gasoline tank. The clear-cut insomnia experiment corresponds precisely with our other brain-suprarenal observations.

With these three kinetic organs we may surely associate also the "furnace," the muscles in which the energy provided by the brain, suprarenals and liver, plus oxygen, is fabricated into heat and motion.

Benedict in his monumental work on metabolism has demonstrated that in the normal state, at least, variations in the heart beat parallel variations in metabolism. He and others have shown that all energy of the body, whether evidenced by heat or by motion, is produced in the muscles. In the muscles then, we find the fourth vital link in the kinetic chain. The muscles move the body, circulate the blood, effect respiration, and govern the body temperature. They are the passive servants of the brain-suprarenal-liver syndrome.

Neither the brain, the suprarenals, the liver, nor the muscles, however, nor all of these together, have the power to change the rate of the expenditure of energy; to make possible the increased expenditure in adolescence, in pregnancy, in courting and mating, in infections. No one of these organs, nor all of them together, can act as a pacemaker or sensitizer. The brain acts immediately in response to the stimuli of the moment; the suprarenals respond instantly to the fickle brain and the effects of their actions are fleeting; the liver contains fuel only and cannot activate, and the muscles in turn act as the great furnace, in which the final transformation into available energy is made.

Another organ—the thyroid—has the special power of governing the *rate* of *discharge* of energy; in other words, the thyroid is the pace-maker. Unfortunately, the thyroid cannot be studied to

advantage either functionally or histologically, for there is as yet no available test for thyroidism in the blood as there is for adrenalin, and thyroid activity is not attended by striking histologic changes. Therefore the only laboratory studies which have been satisfactory thus far are those by which the iodin content of the thyroid has been established. Iodin is stored in the colloid lacunæ of the thyroid and in combination with certain proteins is the active agent of the thyroid.

Beebe has shown that electrical stimulation of the nerve supply of the thyroid diminishes the amount of iodin which it contains and it is known that in the hyperactive thyroid in Graves' disease the iodin content is diminished. The meagerness of laboratory studies, however, is amply compensated by the observations which the surgeon has been able to make on a vast scale—observations which are as definite as are the results of laboratory experiments.

The Thyroid.

The brain-cells and the suprarenal glands are securely concealed from the eye of the clinician, hence the changes produced in them by different causes escape his notice, but the thyroid has always been closely scrutinized by him. The clinician knows that every one of the above mentioned causes of increased brain-cell, suprarenal, liver and muscle activity may cause an increase in the activity of both the normal or the enlarged thyroid; and he knows only too well that in a given case of exophthalmic goiter, the same stimuli which excite the brain, the suprarenals, the liver, and the muscles to increased activity will also aggravate this disease.

The function of the thyroid in the kinetic chain is best evidenced, however, by its rôle in the production of fever. Fever results from the administration of thyroid extract alone in large doses. In the hyper-activity of the thyroid in exophthalmic goiter, one sees a marked tendency to fever; in severe cases there is daily fever. In fact, in Graves' disease we find displayed to an extraordinary degree an exaggeration of the whole action of the kinetic mechanism.

We have stated that in acute Graves' disease there is a tendency to the production of spontaneous fever, and that there is a magnified diurnal variation in temperature which is due to an increased output of energy in even the normal reaction producing consciousness. In

Graves' disease there is, therefore, a state of intensified consciousness, which is associated with low brain thresholds to all stimuli—both to stimuli that cause muscular action and to stimuli that cause fever. The intensity of the kinetic discharge is seen in the constant fine tremor. It is evident that the thresholds of the brain have been sensitized. In this hypersensitization we find the following strong evidence as to the identity of the various mechanisms for the production of fever. In the state of superlative sensitization which is seen in Graves' disease, we find that the stimuli that produce muscular movement, the stimuli that produce emotional phenomena and the stimuli that produce fever are as nearly as can be ascertained equally effective. Clinical evidence regarding this point is abundant, for in patients with Graves' disease we find that the three types of conversion of energy resulting from emotional stimulation, from nociceptor stimulation (pain), and from infection stimulation are, as nearly as can be judged, equally exaggerated. In the acute cases of Graves' disease the explosive conversion of latent energy into heat and motion is unexcelled by any other known normal or pathological phenomenon. Excessive thyroid secretion, as in thyrotoxicosis from functioning adenomata, and excessive thyroid feeding, cause all the phenomena of Graves' disease except the exophthalmos and the emotional facies. Ligation of arteries, division of nerve supply and excision of part of the gland may reverse the foregoing picture and restore the normal condition. The patient notes the effect on the second day and often within a week is relatively quiescent. On the contrary if there is thyroid deficiency there is the opposite state, a reptilian sluggishness.

At will, then, through diminished, normal or excessive administration of thyroid secretion, we may produce an adynamic, a normal, or an excessively dynamic state. By the thyroid influence, the brain thresholds are lowered and life becomes exquisite; without its influence the brain becomes a globe of relatively inert substance. Excessive doses of iodin alone cause most of the symptoms of Graves' disease. The active constituent of the thyroid is iodin in a special protein combination. Thus is stored in the colloidal spaces. Hence one would not expect to find changes in the cells of the thyroid gland as a result of increased activity unless it be prolonged.

We have thus far considered the normal rôles played by the brain, the suprarenals, the liver, the muscles and the thyroid in transforming latent into kinetic energy in the form of heat and motion as an adaptive response to environmental stimuli.

The argument may be strengthened, however, by the discussion of the effect of the impairment of any of these links in the kinetic chain upon the conversion of latent into kinetic energy.

Effect Upon the Output of Energy of Impaired or Lost Function of Each of the Several Links in the Kinetic Chain.

1. *The Brain: Cerebral softening.*—In cerebral softening we may find all the organs of the body comparatively healthy excepting the brain. As the brain is physically impaired it cannot normally stimulate other organs to the conversion of latent energy into heat or into motion, but on the contrary in these cases we find feeble muscular and intellectual power. I believe also we find that in patients with cerebral softening, infections such as pneumonia show a lower temperature range than in patients whose brains are normal.

2. *The Suprarenals.*—In such destructive lesions of the suprarenal glands as Addison's disease one of the cardinal symptoms is a subnormal temperature and impaired muscular power. Animals upon whom double adrenalectomy has been performed show a striking fall in temperature, muscular weakness—after adrenalectomy the animal may not be able to stand even—and progressive chromatolysis. The significance of the last will be pointed out later.

3. *The Liver.*—When the function of the liver is impaired by tumors, cirrhosis, or degeneration of the liver itself, then the entire energy of the body is correspondingly diminished. This diminution of energy is evidenced by muscular and mental weakness, by diminished response and by a gradual loss of efficiency which finally reaches the state of asthenia.

4. *The Muscles.*—It has been observed clinically that if the muscles are impaired by long disuse, or by a disease such as myasthenia gravis, then the range of production of both heat and motion is below normal. This is in agreement with the experimental findings that anesthetics, curare, or any break in the muscle-brain connection causes diminished muscular and heat production.

5. *The Thyroid.*—In myxedema one of the cardinal symptoms is a persistently subnormal temperature and though prone to infection, subjects of myxedema show but feeble febrile response and readily succumb. This clinical observation is strikingly confirmed by laboratory observations; normal rabbits subjected to fear showed a rise in temperature of from one to three degrees while two rabbits whose thyroids had been previously removed and who had then been subjected to fright showed much less febrile response. Myxedema subjects show a loss of physical and mental energy which is proportional to the lack of thyroid. Deficiency in any of the organs of the kinetic chain causes alike loss of heat, loss of muscular and emotional action, of mental power and of the power of combating infections—the negative evidence thus strongly supports the positive. By accumulating all the evidence we believe we are justified in associating the brain, the suprarenals, the thyroid, the muscles and the liver as vital links in the kinetic chain. Other organs play a rôle undoubtedly, though a minor one. If our conclusions are sound, then in the kinetic system we should find an explanation of many diseases, and having found an explanation, we may find new methods of combating them.

Kinetic Diseases.

In the foregoing conclusions we find a simple explanation of certain diseases. When the kinetic system is driven at an overwhelming rate of speed—as by severe physical injury, by intense emotional excitation, by perforation of the intestines, by the pointing of an abcess into new territory, by the sudden onset of an infectious disease, by an overdose of strychnin, by a Marathon race, by a grilling fight, by foreign proteins, by anaphylaxis,—the result of these acute overwhelming activations of the kinetic system is clinically designated shock, and according to the cause is called traumatic shock, toxic shock, anaphylactic shock, drug shock, etc.

The essential pathology of shock is identical whatever the cause. If, however, instead of an intense overwhelming activation, the kinetic system is continuously or intermittently overstimulated through a considerable period of time, as long as each of the links in the kinetic chain takes the strain equally the result will be excessive

energy conversion, excessive work done; but usually, under stress, some one link in the chain is unable to take the strain and then the evenly balanced work of the several organs of the kinetic system is disturbed. If the brain cannot endure this strain, then neurasthenia, nerve exhaustion, or even insanity follows. If the thyroid cannot endure the strain it undergoes hyperplasia, which in turn may result in a colloid goiter or in exophthalmic goiter. If the suprarenals cannot endure the strain, cardiovascular disease may develop. If the liver cannot take the strain then death from acute acidosis may follow, or if the neutralizing effect of the liver is only partially lost, then the acidity may cause Bright's disease. Over-activation of the kinetic system may cause glycosuria and diabetes.

Identical physical and functional changes in the organs of the kinetic system may result from intense continued stimulation from any of the following causes, excessive physical labor, athletic exercise, worry or anxiety, intestinal auto-intoxication, chronic infections such as oral sepsis, tonsillitis and adenoids; chronic appendicitis, chronic cholecystitis, colitis, and skin infections; the excessive intake of protein food (foreign protein reaction); emotional strain, pregnancy, stress of business of professional life—all of which are known to be activators of the kinetic system.

From the foregoing statements we are able to understand the muscular weakness following fever; we can understand why the senile have neither muscular power nor strong febrile reaction; why long-continued infections produce pathologic changes in the organs constituting the kinetic chain; why the same pathologic changes result from various forms of activation of the kinetic system. In this hypothesis we find a reason why cardiovascular disease may be caused by chronic infection, by auto-intoxication, by overwork, or by emotional excitation. We now see that the reason why we find so much difficulty in differentiating the numerous acute infections from each other is because they play upon the same kinetic chain. Our postulate harmonizes the pathological democracy of the kinetic organs, for it explains not only why in many diseases the pathological changes in these organs are identical, but why the same changes are seen as the result of emotional strain and overwork. We can

thus understand how either emotional strain or acute or chronic infection may cause either exophthalmic goiter or cardiovascular disease; how chronic intestinal stasis with the resultant absorption of toxins may cause cardiovascular disease; neurasthenia or goiter. Here is found an explanation of the phenomena of shock, whether the shock be the result of toxins, of infection, of foreign proteins, of anaphylaxis, of psychic stimuli, or of a surgical operation with its combination of both psychical and traumatic elements.

This conception of the kinetic system has stood a crucial test by making possible the shockless surgical operation. It has offered a plausible explanation of the cause and the treatment of Graves' disease. Will this kinetic theory stand also the clinical test of controlling that protean disease bred in the midst of the stress of our present-day life? Present-day life, in which one must ever have one hand on the sword and the other on the throttle, is a constant stimulus of the kinetic system. The force of these kinetic stimuli may be lessened at the cerebral link by intelligent control—a protective control is empirically attained by many of the most successful men. The force of the kinetic stimuli may be broken at the thyroid link by dividing the nerve supply, reducing the blood supply, or by partial excision; or if the suprarenals feel the strain, the stimulating force may be broken by dividing their nerve supply, reducing the blood supply, or by partial excision. No theory is worth more than its yield in practice, but already we have the shockless operation, the surgical treatment of Graves' disease, the control of shock and the acute infection by overwhelming morphinization.

Conclusions.

To become adapted to their environment animals are transformers of energy. This adaptation to environment is made by means of a system of organs evolved for the purpose of converting potential energy into heat and motion. The principal organs and tissues of this system are the brain, the suprarenals, the thyroid, the muscles and the liver. Each is a vital link—each plays its particular rôle and one cannot compensate for the other. A change in any link

of the kinetic chain modifies proportionately the entire kinetic system, which is no stronger than its weakest link.

In this conception we find a possible explanation of many diseases —one which may point the way to new and more effective therapeutic measures than those now at our command.

CLEVELAND, O.,
April 23, 1914.

NEWER ASPECTS AND METHODS IN THE STUDY OF THE MECHANISM OF THE HEART-BEAT.

By ALFRED E. COHN, A.B., M.D.

(*Read April 23, 1914.*)

The interest now very widespread, in the physiology of the heart-beat developed from certain observations which Carlo Matteucci made some seventy-two years ago, and which he communicated in 1842 to the Academy at Paris. He established the fact that the muscle of a nerve-muscle preparation contracted if its nerve were laid across a second muscle which had been made to contract. He believed that the stimulus which the nerve received, and which it conveyed to its attached muscle was electrical in nature. Thirteen years later, in 1855, Kölliker and H. Müller widened the scope of Matteucci's observations by demonstrating in the same way that, if the nerve of a similar nerve-muscle preparation were laid across a heart, the muscle of the preparation likewise contracted, because, as in Matteucci's experiment, a current, called a current of action, was discharged from the contracting heart and was conveyed to the muscle.

These discoveries continue to be the primary subjects of experiment in contemporary studies in the mechanism of the heart-beat. The first experiments dealing with action currents were made by Marchand, Engelmann, and by Burdon-Sanderson and Page, who used a Bernstein rheotome in their investigations, but later the use of the capillary electrometer of Lippmann was introduced, especially by Marey, Waller, by Bayliss and Starling, Gotch and others. Marey in 1876 was the first to obtain permanent records of the action currents of the heart by photographing the motions of the meniscus of the mercury column of the electrometer on a moving sensitive surface. This record was a continuous curve in which could be distinguished various waves, one of which has been identified as synchronous with the contraction of the auricles, the upper chambers

of the heart, and certain others with the contraction of the ventricles, the lower pair of heart chambers. At first all records were obtained by applying electrodes directly to the surface of the heart as it lay exposed in the opened chest, but in 1889 Waller showed that one could obtain records of these currents by applying suitably constructed electrodes to the surface of the body without opening or injuring it. This discovery opened the way for studying these currents in the human subject. Waller also showed which were favorable and which unfavorable locations for placing electrodes, by varying the situation at which they were applied. From a consideration of records ob-

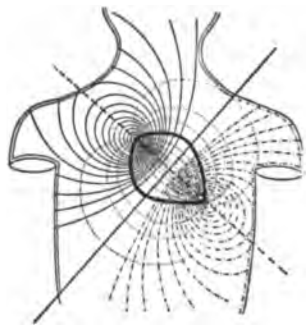


Fig. 1. After Waller. To indicate the spread of the cardiac action current through the human subject.

tained from a number of positions, now called leads or derivations, he determined the location of a plane, on the two sides of which the greatest differences in potential were developed (Fig. 1). Those locations were called favorable which yielded curves showing the largest waves, and the records were called electrocardiograms. The differences between electrocardiograms taken indirectly in this way and those taken directly from the surface of the heart are ones of contour and do not involve the important time relations of the various elements composing the curve.

With the knowledge that the heart discharged action currents, and a method for conducting these from the uninjured surface of the body to a registering instrument, the time was ripe for the construction of a galvanometer better fitted to the purposes of physiological and medical research. W. Einthoven of Leyden in 1902–6 described and built this instrument. Its completion at that time was

especially fortunate, for fresh discoveries in anatomy and physiology were almost simultaneously announced. In the interpretation of the significance of these, the galvanometric method of registration was especially valuable.

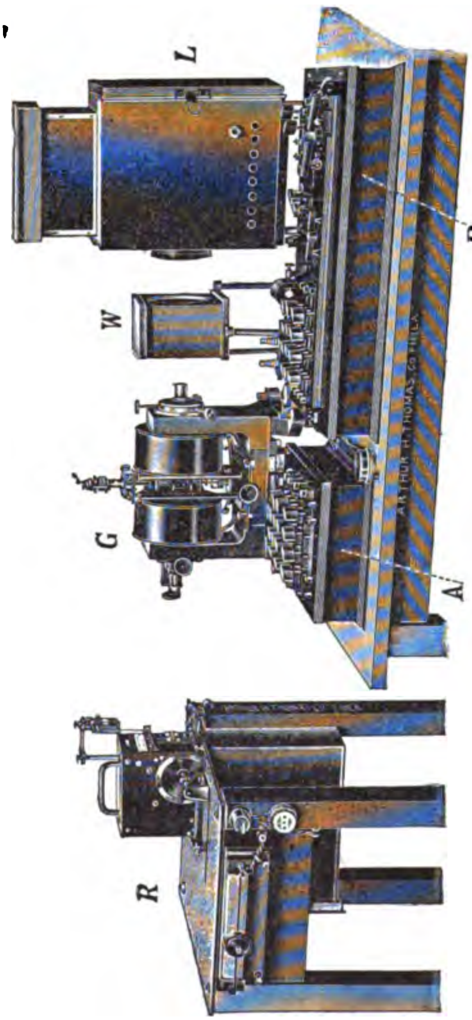


FIG. 2. String galvanometer, Edelmann's model. *R*, photographic recorder; *G*, galvanometer; *L*, arc light; *W*, water-bath; *A* and *B*, resistance and compensating boxes.

The principles Einthoven employed were in use in Deprez-D'Arsonval's instrument. From these he developed formulæ which formed the basis of the galvanometer he constructed. An instru-

ment built on similar lines for use as an ocean telegraph recorder had already been devised by Ader, but of this he was unaware at the time. It depends on the principle that a conductor suspended in a magnetic field is deflected at right angles to the lines of force when a current passes through it. The conductor chosen is usually a silvered quartz or platinum thread, 87 to 100 mm. long, 3 to 6 micra thick, having a resistance of 3,000 to 6,000 ohms It is suspended vertically between the poles of two powerful electro-magnets (Fig. 2). The thread is illuminated by the rays of an arc light which are focused on it by a system of lenses and a substage condensor. To accommodate this condensor the pole of one electro-magnet is bored. The motions of the string are magnified and projected on a recording photographic surface by a microscope held in a similar bore in the pole of the other electro-magnet. The degree of magnification may be varied according to the needs of the investigator, but, in order to maintain a degree of uniformity in the appearance and in the electrical value of curves obtained in different laboratories, certain arrangements have become conventional. These include the strength of the magnetic field, the tension of the string and its deflection time. The strength of the field depends, of course, on its construction. The tension of the string is adjusted in an appropriate manner so that a current having the value of one millivolt, when allowed to pass through it, causes a deflection of 1 cm. It has been found desirable to obtain a deflection of this extent within a definite length of time, usually 0.02 seconds or less. When the deflection time is longer, certain waves in the electrocardiogram tend to disappear.

But in order to obtain an electrocardiogram, more is necessary than to include an individual in the string circuit. For although the usual cardiac action current does not deflect the string, when it is at the prescribed tension, beyond the optical field, the skin or constant current, which is also continuously discharged from the body, and which is composed of the summed discharges from the other electrically active tissues of the organism, may do so, and it is usually sufficiently great to deflect the string far beyond the field of the microscope. This current does not show the rapid changes of potential difference that the action current from the heart does. On the

whole, its strength is uniform and changes so little within small limits of time as to render the change negligible. There is consequently no danger of confusing it with the rapid changes in electrical potential which compose the electrocardiogram. In order to keep the string in the optical field, from which the constant or skin current tends to deflect it, a system of compensation has been found necessary. This system comprises another source of current, a commutator and a series of resistances which are introduced into the string-heart circuit. The action current to be recorded, and with it the constant current, are permitted by a shunt to pass through the string in increasing amounts, so enabling one to allow a sufficient electromotive force of opposite polarity to the skin current to enter the circuit. Compensation in routine examinations becomes a simple procedure. To complete the records, a time curve and a millimeter scale are photographed on the record.

The most fruitful method of investigating the identity of the parts of the electrocardiogram has probably been that of recording synchronously on the same curve the electrocardiogram and mechanical curves representing the motions of the heart. As the result of these studies, it has been concluded that the contraction of the auricles is represented electrically by the *P* wave, the first wave in the cardiac cycle (Fig. 4), while the Waves *Q, R, S, T,* which follow it form a group in the electrocardiogram which are associated with ventricular activity. The term ventricular activity is purposely chosen, for there is as yet no uniformity of opinion in respect to designating which ventricular function it is which this complex of waves represents. Opinion is divided as to whether the complex represents the act of conduction, the state of muscular irritability, or actual contraction. It is doubtless unprofitable to analyze this discussion, and probably quite impossible to decide between these interpretations now. Of this much one can be certain, that the *QRST* complex does not occur unless the ventricles have been seen or known to contract. The significance of the individual waves of this group is also still a matter wrapped in doubt. Most writers favor the view that the wave *Q*, when present, signifies that the earliest ventricular activity has taken place near the apex of the heart, that the *R* wave represents the assumption of predominance

by the ventricular base, while S indicates a return of activity to the apex. The significance of the T wave is a hotly disputed point. Some hold it to represent the return of activity to the base of the ventricles in the later part of systole, because of an analogy which is drawn between the arterial base of the heart and the distal end of the primitive cardiac tube, which is, of course, the last segment to become affected by the wave of peristalsis which passes over it. The most important arguments against this interesting assumption have been supplied by Garten and his pupils, Clement and Erfmann. These investigators have all shown that the T wave occurs at the same instant of time at all points on the heart's surface, and refer its occurrence, as does also Einthoven, to a function inherent in muscular contraction. According to these authors, it represents the second wave in a current essentially diphasic. One need scarcely point out the fact that its presence simultaneously throughout the cardiac surface precludes the possibility of its occurring as the end phase of a peristaltic contraction.

Aside from the auricular representative and the group of waves representing ventricular activity, two other portions of an electrocardiographic curve must be described. The less debated of these is the portion following the T wave, the isoelectric period between the end of T and the beginning of P. It represents the diastole of the heart cycle,—from the end of the ventricular to the beginning of the next auricular contraction,—the rest period of the heart. The other portion is that lying between the wave P and the complex $QRST$; this portion also is usually isoelectric, but occasionally, as Einthoven has pointed out, its level departs from the base line. It is the period which represents the time occupied by the passage of impulses from the contracting auricles to the beginning of ventricular activity, and is called the conducting period.

We must now return to consider those other newer aspects of the study of the mechanism of the heart-beat to which I have referred in speaking of recent anatomical and physiological contributions. Before 1883 the theories held to explain coördination between the upper or auricular pair of the cardiac chambers and the lower ventricular pair consisted principally of an old notion of Haller's to the effect that the ventricles contracted in response to stimuli conveyed

to them by the act of filling, while others held and some do still that coördination between the two pairs rested on a carefully adjusted mechanism involving the passage of impulses over nervous channels. The need for theories of this sort lay in the fact that no muscular connection between the auricles and ventricles was known to exist. But in 1883, W. Gaskell convinced himself that the conduction of impulses in the heart must pass over muscular pathways, and Wooldridge and Tigerstedt contributed experiments which pointed to the

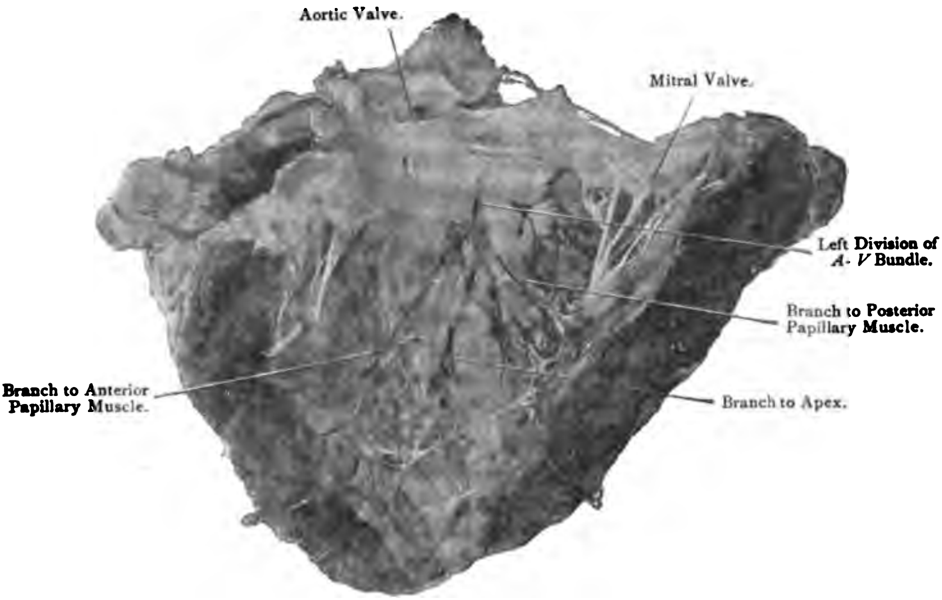


FIG. 3. Ox-heart. Injection with dilute India ink of the bursa-like spaces surrounding the left branch of the *A–V* bundle.

probability of Gaskell's contention. Ten years later (1893) Stanley Kent and His, Jr., actually saw and described a bundle of connecting muscular fibers. Since then (1893–1908) the existence of this structure, best called the auriculo-ventricular bundle, has been sufficiently confirmed. It passes from the lowest level of the auricles, divides into two and supplies a branch to each ventricle (Fig. 3). It has a peculiar muscular structure. In some species it contains large neural elements, but in man and the higher mammals only fine nerve fibrillæ

are found within it. With the establishment of the fact that the auriculo-ventricular bundle possessed this mixed structure, discussion as to whether conduction was nervous or muscular has gone out of fashion. Its essential function consists in conducting impulses and so coördinating the rhythms of the auricles and ventricles. To prove that it actually performs this function, its structure has been destroyed in experiments. In these the result anticipated was realized; auricles and ventricles continued to beat, each at a rate of its own and each in a rhythm without reference to the other. Two other facts are known about this bundle; first, that it can conduct impulses in a backward direction (from ventricles to auricles) as well as forwards; and second, that it conducts a little slower, especially at its upper terminal, than the rest of the heart muscle. We shall return to a consideration of this structure in relation to electrocardiography.

In 1906 another structure situated at the junction of the superior vena cava and the right auricular appendix was discovered by Keith and Flack. It is a small structure called the sino-auricular node. It has a sectional area of 0.3 by 0.1 cm., and attains a length of from 2.0 to 3.0 cm. Its existence has been abundantly verified. Like the conduction bundle, it also contains large and fine nerve elements. The comparative anatomy of both these structures has been traced by Ivy Mackenzie and by Külbs, while the embryology has been studied by Professor Mall. It is the discovery of these two structures, the sino-auricular node and the auriculo-ventricular system, which has added a second new and significant chapter to our store of information relating to the mechanism of the heart-beat.

The sino-auricular node has been recognized as the structure which usually initiates impulses for the contraction of the whole heart, and at the same time sets and maintains its rate. These properties have been attributed to it because excision or exclusion of the node from function reduces the rate of the heart-beat, and sometimes even stops it. Afterwards it begins gradually to contract again, but the original rate is not restored. It can usually be shown that another portion of the heart now sets the pace. Other methods have been employed to ascertain its functions; warmth applied to the site of the node accelerates the rate of the heart; cooling slows it. Attempts to alter the temperature elsewhere of the surface do not

have this effect. But more important information still is gained by means of the galvanometer. It has been demonstrated that each heart-beat begins at the node, because artificial contractions due to stimuli applied here yield curves of a shape identical with those resulting from spontaneous discharges; similar stimuli applied elsewhere fail of this identity. And finally, the law that the site at which contraction begins is primarily negative to other portions of the same strip of muscle is valid here. Lewis and Oppenheimer, Wybauw, Clement and Sulze have all been able to show that in contraction, the site of the node is primarily negative to all other portions of the auricular surface.

We have described the newly discovered structures in the mammalian heart. The function of the sinus node, in so far as it is now known, is to initiate impulses for the whole heart and to determine their rate; Lewis has aptly called it the pacemaker. The auriculo-ventricular bundle provides for coördination in the complicated mechanism of the heart. We must next show how, in the light of these structures, the electrocardiogram has been employed in elucidating the mechanism of the heart-beat. Althought the sinus node and the conduction bundle are very small indeed in comparison with the size of the whole heart, it is chiefly to these that the attention of investigators has been directed, while to the great mass of the organ which is charged with the real work of carrying on the circulation, very little research has been devoted. Our account of the electrophysiology of the heart must, therefore, be necessarily incomplete, and incomplete in just the direction in which one had hoped for light, —namely, in an attempt to employ electrical estimations as measures of the contractile force of the heart.

To be useful, the first demand of a method is that it give constant readings, and observation has shown that the electrocardiogram satisfies this demand, for its waves tend to remain unaltered in shape and size. When they alter, an ascertainable disturbance has in many cases been found as the cause. An electrocardiogram is, therefore, a reliable record. Its constancy is illustrated in records obtained from various classes of animals. They have certain characteristics in common, so that one can easily distinguish, for example, electrocardiograms of amphibia from those of the higher mammals. And

of the mammals, the species which have been studied, the horse, rabbit, cat, dog and man, each shows certain definite characters on the basis of which it can be recognized. Einthoven and Lewis and Gilder have studied human electrocardiograms and have defined within certain limits the usual form of curves taken from normal persons. But differentiation can go further, for the records of individuals have been found to differ widely from person to person in health, and more widely still in disease. Whatever form, either normal or abnormal, the curve assumes, this remains characteristic for the individual, for a certain length of time at all events, though the records be registered by different instruments and recorded by different investigators. An electrocardiogram may indeed attain a form so peculiarly personal that the suggestion has actually been made that it be employed to serve the purposes of identification in much the same way as the Bertillon system does. We may therefore regard the electrocardiogram as a valid and reliable record.

A number of the factors which can bring about variations from a normal curve are understood. Some of these may now be enumerated. The auricular wave, in the first place, is modified by the nature of the derivation or lead used; in this case the most favorable situations to employ are usually the two upper extremities, but under certain circumstances two points on the chest wall have been found preferable. A rare and not altogether satisfactorily established defect in the auricular mechanism is a lack of synchronicity between the contractions of the two auricles. This defect has occasionally been found to split the *P* wave. But the most significant alteration occurs when the *P* wave, instead of being directed upward, the direction which in the usual arrangement is associated with primary negativity at the site of the sinus node, is directed downward, an alteration which presumably shows that primary negativity has occurred at a lower level of the auricles. This change takes place when the sinus node is excluded from function, and when another part of the auricle sets the pace instead, but it also occurs spontaneously as the result of causes, the nature of which is not clear. It has been our good fortune to observe on a few occasions a gradual transition from *P* waves directed upward to *P* waves directed downward; if the apices of succeding *P* waves in such curves are joined, a curved line results.

This very curious phenomenon depends on an obscure mechanism, and unfortunately we have no satisfactory explanation for it. We know that where we have seen it best, it was associated with accidental intoxication by the drug digitalis. But we have seen indications of it in other connections which render its interpretation impossible with our present knowledge.

Some of the changes which are observed in the ventricular electrocardiogram are more easily explained. Considered as a whole, that is to say, in the light of the three usual leads of Einthoven (the first from the two arms, the second from the right arm and the left leg, and the third from the left arm and the left leg), one obtains a great many curves in which the waves in the first lead are inverted, and others in which inversion takes place in the third lead. Changes such as these result from a variety of causes. A heart which is not firmly anchored, but is easily shifted within the chest cavity by changes in the position of the body, may yield curves in which inverted waves appear. Comparable changes may result when the heart is pushed by air or fluid introduced in the chest, or when it is pulled to one or the other side by bands of adhesion stretched between the heart's surface and the chest wall. The explanation now offered for these phenomena by Einthoven and others is that the relation, determined by Waller, of the electrical axis of the organ to the body axis has become altered. Similar causes are probably at work in the electrical changes which are seen in increases in size of the heart, whether due to dilatation of its cavities, or to thickening of its walls; and the curves vary according to which side of the organ is involved. When the right side undergoes these changes, it is in the first lead that the ventricular waves become negative (Fig. 4); when it is the left side (Fig. 5), the negative waves appear in the third lead. Although alteration in the relation of the electrical axis and the body axis is the cause, that is to say, the mechanical, anatomical cause, commonly given for such deviations from the normal curve, it appears necessary to remember that in hypertrophy of the heart the balance of the sum of potential differences which produces the normal electrocardiogram must be disturbed, and that a rearrangement, that is to say, a functional rearrangement, of the parts of this sum must occur and might of course result in the changes we

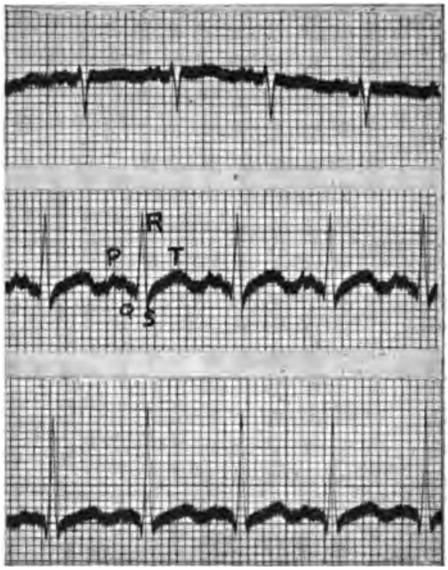


FIG. 4. Electrocardiogram showing the three usual leads of Einthoven. From a heart showing hypertrophy of its right ventricle.

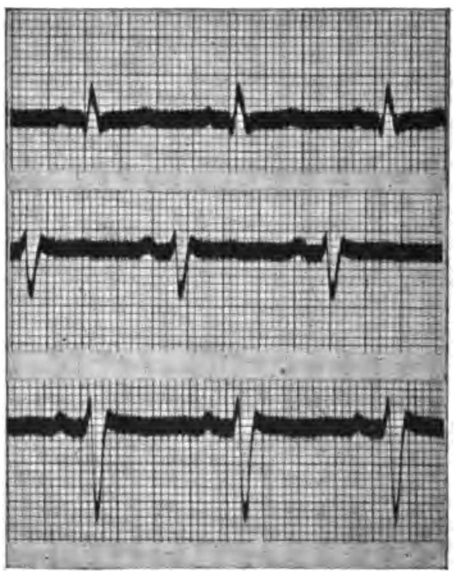


FIG. 5. Electrocardiogram showing the three usual leads of Einthoven. From a heart showing hypertrophy of its left vertricle.

are describing. More exaggerated changes still are observed when there is no alteration, either in the size or in the position of the heart; and these are due to the manner in which impulses are propagated to the ventricles from the contracting auricles. The pathway followed normally has already been described, but now the normal path cannot be taken, for it has been partly destroyed. It has been shown that when the conduction bundle to the right ventricle is

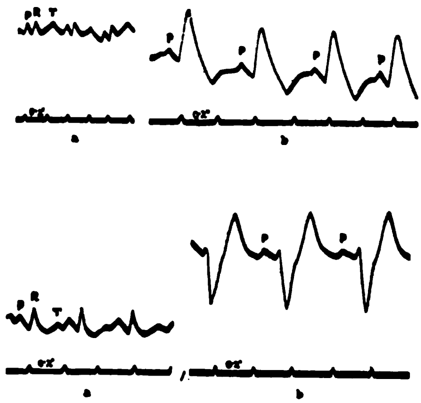


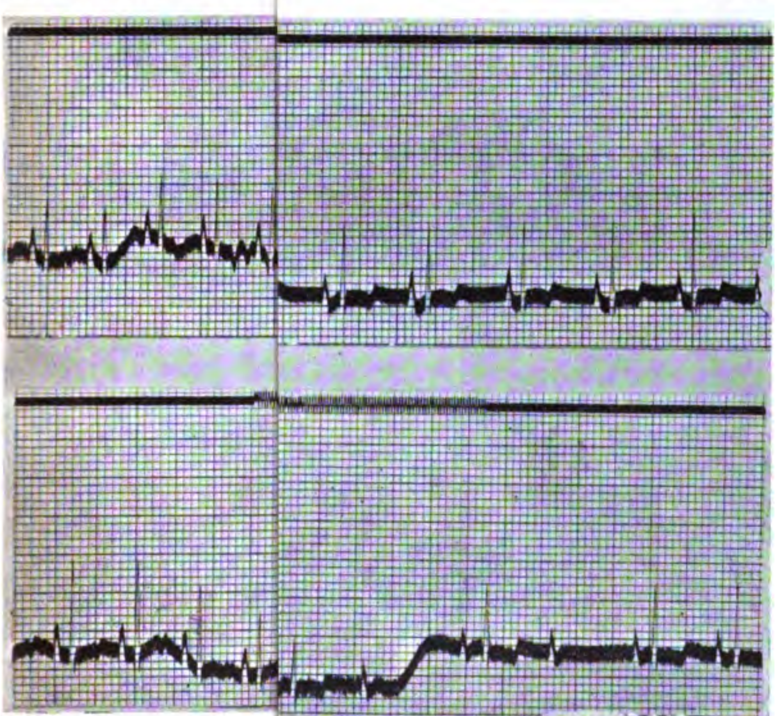
FIG. 6. Electrocardiogram from a dog. Leads from oesophagus and anus. Above: first portion is a control; the second is a curve taken after the left branch of the *A–V* bundle has been cut. Below: control and a curve taken after the right branch of the *A–V* bundle has been cut. After Rothberger and Eppinger.

severed, allowing impulses to reach only the left ventricle, the electrocardiogram immediately takes on another shape, the shape being an exaggeration of what occurs during enlargements of the left side of the heart. The first ventricular wave is sharp downward and the second an upward deflection. If, on the other hand, a similar injury is done to the conduction bundle to the right ventricle, there is a reversal of electrocardiographic curve. It consists of a sharp upward, followed by a downward deflection (Fig 6). Finally, if a curve of one or other form has been obtained by cutting one or other branch of the conducting bundle, one can, by severing the still uninjured branch, obtain an electrocardiogram which differs from both the preceding and resembles, though not exactly, the original curve. These changes depend, then, upon the way impulses pass through

the heart. An explanation of the nature of these abnormal curves is obtained by comparing them with others from hearts to which direct mechanical stimuli have been applied. A stimulus to the left side of the heart (ventricle) yields a curve like that seen when the right branch of the conducting bundle is cut, while one applied to the right side is like the curve seen when the left tract is cut. Under both conditions, contraction is initiated at the site of the stimulus, and the impulse spreads over the heart from this area. The form of the curve yielded depends on whether the right or left ventricle initiates the contraction.

The conduction bundle, then, is an important factor in the orderly cardiac mechanism, but, on account of its exposed position in the heart, it is frequently injured. The pathway between the auricles and the ventricles is, therefore, interrupted and impulses from one to the other are consequently blocked. The ventricles, deprived of stimuli from above, contract independently and without reference to the rate or rhythm of the auricular beats. In the study of derangements of the cardiac mechanism of this nature, electrocardiography has rendered distinct service.

So far we have discussed the mechanism of the heart-beat only in so far as it relates to the intrinsic arrangements of the heart. But for the proper exercise of a number of its functions, the heart is subjected to the influence of the central nervous system. In the study of this influence the galvanometer has been not only useful, but essential. Branches from the central nervous system to the heart exercise functions of two sorts,—inhibitory and accelerator. It has been especially our work to show that the inhibitory or slowing function is not simple and is not possessed equally by both vagus nerves. To say that the right vagus nerve principally modifies the rate of the heart and the left vagus chiefly conduction between its chambers states a truth and also indicates the presence of a complicated mechanism which may be explained in the following way: The complexity depends on the fact that the heart was originally an unpaired organ with a symmetrically distributed nerve supply. This supply, so far as we are informed, was directed to the junction between the old sinus venosus and the auricles. In the development of the heart, a division of the junctional tissue took place; one portion, the right,



Electrocardiogram fr n of the left vagus nerve. Divisions of the
rdinates are 0.1 millivolt; of

remained at its original level, but became incorporated in the wall of the right auricle as the sinus node; the other portion, the left, became dislocated and moved downward the distance of a whole chamber, becoming, in the adult mammalian heart, the auriculo-ventricular node which lies between the auricles and the ventricles. The importance of these changes in position, from the point of view of innervation, lies in the fact that the cardiac branches of the two vagus nerves, which were distributed symmetrically in the primitive heart, have followed the changed positions of the structures they innervated originally and have become incorporated with them in their new situations. Consequently, the nodes and their nerves have assumed different functions. We were led to believe that this change must have taken place, first by clinical observation, and we have tested this hypothesis by experiment. As the result of experiments on many dogs, we were able to decide that when the right vagus nerve was electrically stimulated, the heart stopped beating. But when the left vagus nerve was stimulated, the auricles did not stop beating, but continued, though often at a slower rate. The striking thing now observed was that these auricular beats failed, either entirely or only occasionally, of being followed by a ventricular response (Plate II).

These were the facts. In the light of current teaching, the motions of the heart are initiated and rate is maintained by the sinus node. Impulses so initiated are conducted from the auricles to the ventricles over the narrow conduction path, with which we have become familiar. It follows that, when we find the heart stop as the result of a stimulus, we must assume the stimulus to have been distributed to that portion of the heart where the pace-making function resides, that is to say, at the sinus node. In the same way, when a disturbance in coördination between auricles and ventricles occurs, we have sufficient evidence to indicate that this occurs as the result of an effect produced at the junctional connecting tissues. We must, therefore, conclude that if stimulation of the left nerve brings about this disturbance, it must necessarily be distributed to this portion of the heart, that is to say, to the conducting system. Although we think that these sites, the sino-auricular and the auriculo-ventricular nodes, are the main terminals of these nerves, it is clear that other functions

are influenced at the same time when they are stimulated. We have indeed shown that this is the case. But our main concern has been to obtain information about essential differences; the likenesses and the additional influences exerted will be apparent. In this problem again, the galvanometer has been invaluable. On the basis of ordinary mechanical records, of which we have made many in the course of this work, we could not have drawn the conclusions just detailed.

Stimulation of the augmentor nerves shows that these have distributions similar to those of the inhibitors. Rothberger and Winterberg have contributed these facts. They have shown that stimulation of one or other augmentor nerve produces effects which can be referred to a modification of the function of the special cardiac tissues we have discussed in connection with the inhibitory nerves; and they have also shown that other differences of an electrocardiographic nature take place.

We have traced, in recording the newer aspects and methods of the study of the heart-beat, the influence exerted by the introduction of electrical methods. Advances by this method were due in large measure to the construction of an adequate galvanometer. But the advances in our understanding of the heart have depended on detailed anatomical and physiological investigation of the newly discovered structures in the heart itself. How small a portion it is that has been studied in relation to the whole heart, and how relatively few functions of the efficient organ have been included in the recent investigations, has been indicated. Much remains to be done by the means at our command, but much also by others still to be devised.

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THE USE OF A PHOTOGRAPHIC DOUBLET IN CATALOGUING THE POSITIONS OF STARS.

By FRANK SCHLESINGER.

(Read April 24, 1914.)

In order to utilize for cataloguing and for similar purposes the positions of stars derived from photographs, it is necessary to know the scale of the plates, their orientation and their positions in the sky. In the early days of astronomical photography attempts were made to determine the scale and the orientation by such methods as measuring the absolute focal length of the photographing telescope, and by impressing an orienting star trail upon the plate. These attempts have not been successful and it has now become the universal practice to employ comparison stars for these purposes: that is, stars that appear on the plate with positions known in advance, usually through observations with the meridian circle. Here again experience has shown that in the determination of star places by photography, this matter of comparison stars is usually the weakest link in the chain. For example, in the case of the Astrographic Catalogue much of the relatively high precision with which the plates can be measured is lost on account of the lack of suitable comparison stars.

An experiment that aims to overcome this difficulty is in progress at the Allegheny Observatory. Instead of employing a simple objective to photograph the stars, a doublet lens is used. This has the advantage of much greater extent of field of good definition, at least six times as great as in the case of the objectives used for the Astrographic Catalogue. Consequently in surveying any large area of the sky, plates taken with the latter kind of telescope will require (other things being equal) six times as many comparison stars as the doublet.

The use of the doublet for these purposes was advocated twenty-five years ago by Pickering, but astronomers have feared that the use of such an objective might introduce serious errors of various kinds. The experiments already completed at Allegheny prove that,

with proper precautions, these fears are groundless and that this form of instrument is admirably adapted for cataloguing purposes. The detailed results of these experiments will soon appear as No. 9, Volume 3 of the "Publications of the Allegheny Observatory." On this occasion it will suffice to give merely the results.

A number of regions covering about twenty-five square degrees each, were photographed in duplicate, first with the center of the plate at the center of the region and then with the edge of the plate in that position. A comparison of the two sets of positions gives

$$0''.18$$

as the probable error of the measurement of one image. This quantity includes not only the accidental error but the following as well: (1) outstanding errors in the measuring engine; (2) the optical distortion of the objective, due to a possible failure of the objective to give a truly linear reproduction of the object photographed; (3) magnitude distortion due to spherical aberration and causing bright stars to appear systematically nearer or systematically farther from the center than faint stars. The result shows that all of these errors are very small, and additional experiments indicate independently that (2) and (3) are negligible or very nearly so.

Doublets have been extensively used in astronomy for pictorial purposes. The doublet that we have used for the above experiments differs in one important respect from these: the ratio of the aperture to its focal length is twenty-one instead of five or six This circumstance is favorable to its performance over a wide field and is doubtless responsible for the smallness of the optical and the magnitude distortions.

Our objective covers well a field of twenty-five square degrees, as compared with four square degrees in the case of the plates for the Astrographic Catalogue. For the latter, as already stated, six times as many comparison stars would be necessary in a large piece of work in order to determine the plate constants equally well. The scale of the astrographic plates is a little more than double that of ours, and the purely accidental error of measurement is therefore somewhat smaller, but not as much smaller as this difference in scale would imply. In practice, so much of the accuracy of photographic positions depends upon the comparison stars, that if a large area

were to be surveyed with both instruments and the same comparison stars were used in the two cases, our doublet would give the more accurate results. If there were at hand in some special case comparison stars that are much superior in number and in accuracy to those that are generally available, then the astrographic plates would give the better positions. Needless to say, a doublet like ours with twice its aperture and twice its focal length would give still better results, but this would necessitate plates about 35 centimeters square and a measuring engine large enough to accommodate them.

Our objective would also be well adapted for compiling zone catalogues of faint stars similar to those of the *Astronomische Gesellschaft*. The latter now extend from 80° north declination to 18° south, a work that has required the cooperation of sixteen observatories during a considerable number of years. Observations are in progress that will extend this catalogue farther south, but no provision has yet been made for the southernmost zones. When these come to be actively considered, the claims for the doublet should be carefully weighed. The original plans for the Gesellschaft Catalogue included the repetition of the observations after the lapse of about half a century. This time is now approaching in the case of some of the northern zones, though others (notably the one between 70° and 75°) are of more recent origin. The repetition of all the northern zones, if carried out photographically by means of a doublet, would be a task well within the powers of a single observatory. Moreover there would be a very considerable gain in accuracy. From the prefaces to the various zones of the Gesellschaft Catalogue we learn that the probable error of one observation in either right ascension or declination is on the average well over 0".50. This was derived from observations made with the same telescope on different nights, and does not include certain errors that would be brought out by comparing observations made at different observatories. Our plates yield for the probable error of one observation, 0".18. This was obtained by comparing overlapping plates, but it does not include errors due to inaccuracies in the positions of comparison stars.

Although the tests we have made with our doublet may be ac-

cepted as indicating the size of accidental errors and of certain kinds of systematic error, it cannot be claimed that they tell the whole story. To make certain that star places thus derived are free from serious systematic error of any kind, would require much more observational material and would involve certain extensive intercomparisons as well as comparisons with star positions derived by wholly different methods. Such a work is contemplated at Allegheny and is in fact well under way. The zone extending from declination 2° north to 2° 10′ south is being photographed in duplicate, the centers of one set of plates being upon the eastern or western edges of the other. Each plate will embrace 24 minutes in right ascension or 6°; the program at the telescope therefore calls for 120 plates. To determine the plate constants 602 comparison stars will be employed, an average of ten on a plate. The mean of the two positions for each catalogue star will therefore depend upon about fifteen comparison stars. Thanks to the courtesy and cooperation of Director Campbell and Professor Tucker of the Lick Observatory, the positions of these 602 stars are being determined with the meridian circle of that institution.

Within the limits of declination selected we are measuring the positions of all the stars that appear in the three Gesellschaft zones that overlap. The observing list for the latter was made up of the stars that are designated with (visual) magnitudes 9.0 or brighter in the Bonn Durchmusterung, and as many fainter stars as circumstances permitted. In our work we shall necessarily omit a few stars that are photographically faint by reason of their color, a few stars that are so bright as to present images too large for accurate bisection, and a few doubles that are too close for separation on plates of this small scale. Making allowance for these omissions the completed catalogue will contain about 7,100 stars. It is hoped that this work may not only prove a valuable contribution to our knowledge of the positions and motions of faint stars, but that it may enable astronomers to decide definitely as to the advantages and disadvantages of this form of instrument for the wider applications of the same kind that the future will demand.

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SOME OBSERVATIONS ON THE PSYCHOLOGY OF JURORS AND JURIES.

By PATTERSON DuBOIS.

(*Read April 23, 1914.*)

Interpretation is the crux of science and the chief point of failure in scientific men. When concerned with human behavior it reaches the most subtle nicety—a kind of nicety, indeed, which projects far beyond the helping hand of instruments of precision or mathematical formulæ. Human interpretation is the pivot of human intercourse.

Under the prescriptions of our common jurisprudence the verdict of a court jury is mainly a resultant of many subconscious forces and unseen influences. Standing obviously to reason, this needs no demonstration. Comparatively little of "the evidence" admitted by the court during the trial and little of the pleading operates directly upon the mind of the jury—even though, paradoxically, without these there could be no trial.

It is no part of this paper to attempt the impossible task of unravelling the real or probable complex of past experiences, prejudices, emotions, misunderstandings or logical balances of judgment affecting the minds of the jurors.

Chiefly, it is limited to the proposition that, so far as the juror is concerned, court discipline tends to diminish rather than to increase, and to hamper rather than to facilitate his efficiency as an agency of justice. In other words, the conscientious juryman of good average equipment goes handicapped to his task largely because he is in subjection to an iron rule which takes no note of his individuality of fitness or unfitness, distress or ease, or of other personal and court conditions which themselves condition his judiciality. The problem is largely one of attitudes—a comparatively neglected field in pure or applied psychology.

The court takes cognizance of certain classes of influences likely

to affect the jury mind, giving way to some and aiming to suppress others that tend to prejudice and disturb the equanimity which makes for justice. But the main thesis here is that there are other and subtler influences which are often a still greater menace to justice and that there is little thought of reducing them to a minimum.

Manifestly, this should be the first consideration—just as the reduction of friction and of waste effort are of prime importance to the mechanist. Similarly, a business requiring so much personal sacrifice, such delicate mental balance coupled with resolute and courageous control, such openness to conviction without the weakness of hasty consent,—such a business should be carried on under the most favorable conditions instead of under conditions tending to defeat the desired ends.

In his delicate and often vital responsibilities everything should, as far as possible, conspire toward the best use of the juror's morally controlled intellectual judgment, whereas this judgment is subjected to an automatic conspiracy of obstacles, infirmities, and irritants. He is expected to be, and, in my experience, generally wants to be, free of all forms of bias for which the challenging attorneys take little thought. The juror, indeed, is in no small degree a marionette of which his subconscious self holds the controlling wires while the whole inherited system of trial by so-called peers is the grinning instigator. And the marionette is seldom wholly self-respecting.

All the way down from the earliest English times when witnesses were jurors and jurors were witnesses, gathering their own testimony and acting on their own knowledge, there have been many modifications of the jury system and diverse views as to its value.

The juror's office is, in some respects, the most ironical and paradoxical in the whole range of human service. Its requirements are those of a learned profession with demands of extraordinary versatility. The profession is to be followed by the individual for a very brief period with uncompensating "compensation" (often at an actual loss to the juror.) Yet the juror is so hedged about, officially suppressed and oppressed that the opportunity for initiative, the value of his knowledge, and the freedom of his judgment are reduced to the minimum instead of being employed at their maximum. He is, in effect, both puppet and prisoner.

I am especially considering the juror of the more intelligent and selected class. As a rule, he admits that jury service, in spite of its drawbacks, is educationally profitable and often interesting. He means that his duty shall be conscientiously performed. He is sensitive about sitting in judgment upon his fellows—for he knows his own liability to appear at any time as plaintiff or as defendant. Yet withal, he is asked to swim with a stone on his neck, to be agile in a straight-jacket, to be patiently complaisant in duress—a mental Blondin in hobbles.

His bristles begin to rise, when, in his own home, the summons is served with a threat. The "law" first greets him with flashing eye and teeth uncovered. The more conscientious and honorable the man the more offensive appears the attitude of his legalized captor.

In the United States courts this summons may compel the victim to attend court fifty or a hundred miles away. He may live on a branch road where train service is such that he could not go and come every day. Even if he could, he would be out of pocket since the fee is insufficient to pay the passage. This condition may require the juror to be absent for a week at a time from his business, or from a sick wife, virtually without compensation and really without assurance of release in emergency. How can a man's judgment be at its best under such circumstances?

In any case, whether he lives far or near, the average man on receiving notification that he is wanted is, for the moment at least, disconcerted or timorous. Before him rises the giant of business demands, home dependents, personal physical disabilities or pathological possibilties, a sense of being penalized, of loss of freedom without cause, a danger of "contempt" through sheer ignorance and inexperience, a vision of all-night incarceration with uncongenial strangers, perhaps sickness in his family unwaited upon and beyond communication with him. I doubt whether any jury panel is ever drawn entirely free from some or all of these mental perturbations in some or all of the individuals. They are, however, especially true of the first-time juror. To add to his discomfiture his neighbors either pity his plight or make a jest of it or advise his making an effort to get excused. I have talked with two classes of drawn

men. One never expects to serve if release is possible, another chafes under his weary durance yet says that he ought and means to serve if possible.

Once in the traces and more or less accustomed to the routine the first pressure of the screws is less felt. But, none the less, the juror has a mind and a body. He does not forget that he was born a freeman nor that he is absent from farm or store or office. The delays, the wearisome reiterations and professional fencing, the interruptions and general unbusinesslike pace of procedure are at his cost. They irritate and disgust.

When the juror is drawn from the "panel" to serve on a particular case he is ordered into his seat with pretty much the same show of authority and sense of subjection as he sees when the accused defendant is policed into his presence. In an interesting reminiscence of long and varied jury experience published in a magazine article some years ago Mr. Joseph Hornor Coates speaks deprecatingly of these indignities:

"The juryman from his first entrance in response to the court's peremptory summons finds little in his treatment to impress him with an idea of special dignity in his position, even if he has no overt cause of compliant. He is herded with his fellows, ordered about by the tipstaves or bailiffs of court, addressed in peremptory tones . . . . He sits in the court room with an ever-present sense if he be sensitive, that he must be careful not to get into trouble; the feeling of liberty is gone, he is enveloped in an atmosphere of restraint. Really, he is placed more on an equality with the prisoner at the bar than with the judge on the bench, yet he is as essentially a part of the court as that august potentate and may have at any time a greater responsibility imposed upon him. In some court rooms when disengaged from the actual trial of any case and awaiting summons to the jury-box, the juror is often forced to sit among criminals, witnesses, loafers and ill-smelling persons attracted to the court by business or curiosity."

While the average juror resents these low estimates of his office he does not, perhaps, fully realize how his own judicial faculty is lowered by his lowered estimate of the court as an institution. He becomes critical and dislikes being party to the system.

The juror's disposition to criticize the system (rather than court officers themselves, for the officers naturally fall into the formal bondage of a system) increases through the meanderings of the trial, —the surplussage, the objecting attorney, the lust for filing ex-

ceptions, the hectoring and heckling of witnesses, the muteness of the jury itself, and finally the mistrust of its honor in locking it up to reach an agreement—not always real but formal—all these incite the sensitive and the honorable mind especially to secret rebellion against the system. This state of mind cannot but endanger verdicts.

There are other influences of entirely conscious and purposive kind which affect verdicts too. Thus, in the jury's deliberations under lock and key a juryman will openly confess that he will not vote to acquit a negro prisoner because he *is* a negro; or he will stand by a chauffer in a suit for damages because he himself drives an automobile; or he is moved by fear of the judge to decide against what he has ordered or what he believes to be the judge's opinion; or he is politically afraid; or he dislikes to be the target of ten or eleven others; or he wants to go home, to take the next and last train, perhaps, to avoid another night at a hotel; or he cannot understand the case—its technical terms, its arithmetic, its alternatives, its fine-spun distinctions, some of which are purely technical and have no direct bearing on justice.

But while some of these influences arise directly out of the system and are corrigible they are mostly more obvious and overt than the subconscious causes of mental sway, arising immediately out of juridical prescription and attitude. Some of these have already been noted. Timidity, restraint, sense of personal loss, personal discomfort, offensive environment and treatment, worry over private troubles caused in part by absence from home or business —all of these affect the balances of a sensitive mind and are in a large measure corrigible. The implication that as a juror one cannot be trusted to come and go while the judge and the witnesses and attorneys are free hurts a sensitive mind and excites a rebellious spirit.

In fact, the wearisome reiterations in the examination and cross-examination of witnesses, the time consumed in legal fencing, the objecting and excepting, sometimes give the juror a sense of being unfairly exploited for the gain of attorneys rather than for the settlement of real difficulties. Juries are jealous of their time and personal freedom; so surplus verbiage and legal loquacity irritate to

the extent of damaging a cause—for it is a fact that a verdict or a disagreement is not seldom a slap at a lawyer's course. Many a case is undone by overdoing. This is a hard lesson for lawyers to learn. In his reminiscences of a long life at the bar Theron G. Strong (*The Outlook*) notes this danger of time-wasting excess and overdoing. He says:

> "The man who can say the most good sense and sound law in the shortest time has a decided advantage. Juries are not much influenced by outbursts of eloquence, and appellate tribunals will not tolerate them. A tired and yawning jury will not be likely to take the most favorable view of an advocate's case, and when the attention of an appellate tribunal is lost and the judges begin to converse in whispers or bury themselves in the record, the oral argument is little more than a waste of time. When you have lost attention, you have probably lost your case. Juries and judges have become so accustomed to business-like methods that they appreciate a simple and clear presentation of the essential facts, each argument in its support clearly stated in a few well-conceived sentences, with no haltings and no revertings to things inadvertently omitted, no fumbling of documents, and no reading from authorities . . . .
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> "One of the most important arts of the court lawyer is to know when to keep still, and be able to exercise the self-command to do so. Many a case has been won by paying due regard to the attitude of the judge when he essays to combat the views of opposing counsel. The lawyer is indeed wanting in tact and discretion who then assumes any other rôle than that of a spectator of the proceedings. By all means let the judge do your arguing for you if he is so inclined, and if in this way he indicates that he is favorably disposed it is folly to attempt to reinforce his views; even though they could probably be reinforced to advantage, they do not need reinforcement so long as he adheres to them. The moment the court appears favorably inclined to your side of the case is the time to preserve discreet silence. This is equally true with juries, and if in the course of the trial there is the slightest leaning in your favor, then is the time to do as little as possible by objections or long cross-examinations, which can only have a tendency to lead the court and jury to think that you consider it necessary to strengthen your case when it needs no strengthening, the only effect being to counteract the favorable impression that has been made. Many a case has been spoiled by an inability to recognize the appropriate time to say nothing."

I quote this at some length because few lawyers are so discerning of the juror's point of view. I confess to the feeling of an oncoming bias against the lawyer who is working too hard. Too much repetition of evidence, too many witnesses, too great detail in the pleading, too much swelling molehills to mountains, too noisy oratory—all these excesses tell on the juror's temper. He does not

care to be treated as though he had not the brains to see the bearings of the testimony as it came from the mouths of the witnesses.

The court is quite right in sustaining objections to much extraneous matter that clogs the proceedings and overloads the jurors. But it is questionable whether the loss of time by a large majority of these objections does not tend to irritate jurors who are rightly jealous of their time and critical of a system which compels its loss without corresponding gain to them. Much of the matter ruled out or admitted after a battle between attorneys goes for what it is worth to the jury and not a little of it is without effect on the juror's mind either way, except as a general irritant. Whatever is evidence to his mind *is* evidence and willy-nilly his mind is affected by it. To a juror with imagination and the gift of interpretation evidence is often felt as atmosphere and is much more than the dry bones of admitted testimony.

For instance, in a trial in which the verdict turned chiefly on the motive or purpose of a paper engaging to purchase and pay for a large block of stock on a certain date, the lack of frankness and the constant evasiveness in one of the witnesses so strongly discredited him in the minds of at least half the jury that they virtually agreed that they would not employ such a man in their own businesses. Indeed the other half of the jury did not defend him. As this witness substantially agreed with and was on terms of more or less intimacy with the four others who told the same story the whole five were greatly weakened as witnesses. This was evidence unavoidable in coloring the minds of jurors, although not "evidence" on the record.

Again, in the case of a woman suing for damages as the alleged result of a fall by a defective brick pavement, more than one juror believed that the defense lost an opportunity in not bringing out in cross-examination the height and slope of the heels of her shoes—as these might have been more responsible for her tumble than the pavement itself. But as these jurors did not know anything about it—nothing having been said in court about it—they of course did not openly consider it. But the point is, that even such a case no one knows how far such a passing thought gives cast to the mind

consciously balancing itself to a nicety of honesty and absolute justice. It becomes evidence.

It is questionable whether the cause of justice would not be better served by a much more liberal attitude toward the admission of evidence than our jurisprudence usually allows.

This particular case is also a good illustration of jury-irritation through excess of detail and repetition. Large photographs were displayed and re-displayed and pencil-marked and passed and re-passed among the jury to show the pavement and the curbstone. All witnesses but one corroborated what the photographs were supposed to picture and no juror or any one else probably had any doubt about the pavement or about the slipping of the woman's foot. But it would have been just as effective to show the photographs once and for all, and obtain a simple statement of fewer witnesses without such over-elaboration.

There was a juror, for instance, who was suffering from a racking cough, who lived on a small branch railroad at perhaps fifty miles distance. He had left many business interests. It was now the last day of the term—Saturday. If he lost a certain afternoon train he would lose a whole day in getting home. He knew that a team had been sent for him a dozen miles or so through a snow-drifted country and if he could not catch that train his non-arrival would not be understood. Naturally he looked repeatedly at his watch when every senseless repetition delayed the trial. The judge did his part to push the trial through but there is a limit to the judge's action at least as a matter of expediency. The juror with dismay saw his train-time go by with suppressed irritation. One or two others from other counties were similarly affected. The insistence here is that the trial could have been gone through within half or two thirds of the time it really took. The jury knew no more for the redundancy and were less fit for the balance of their powers than they would be under more favorable conditions. Few men can be at their best as dispensers of justice when they see their valuable time frittered away—for what? To settle a contention in which they have no live interest and for which they are held in duress as though they were not to be trusted out of sight.

Mr. Coates's experience agrees with mine—that the pleadings

of the lawyers have very little direct effect on a substantial jury. In simple cases not involving too much consideration of human nature or of the motives perhaps most jurors catch the drift of the evidence and make up their minds before the trial is through—even though they suppose themselves open to conviction either way.

Lawyers damage their cases—sometimes lose them, by what the jury regards as an unfair trick. Some jurors are affected by the fact that a famous lawyer is on the case—his reputation alone carrying weight.

A very slight thing may bias the juror. One lawyer lost favor with some jurors because of his continual smile and offhand pleasantry in his pleading. Another quite properly asked one of the jurors, whom he called by name, to define a technical business term —the lawyer being or assuming to be not quite sure of it himself. This fact was noted in the juryroom and charged up against that juryman's opinion—one of his confreres asserting that apparent friendship with the plaintiff's attorney affected his judgment. This charge was entirely good natured but was given to offset a charge that the juror favoring the defence was partisan because of his local affiliations—the defendant hailing from the juror's locality. The jury disagreed in this case which was one of great difficulty because of local interests, human motives, and the large losses and gains involved. And yet no one can question the honesty of every juror there —while also no one can help questioning the amount of coloration in the minds of not a few of the jury arising from these causes apart from the formal evidence. It was noteworthy that all the jurors who were of a certain foreign descent and understood the same foreign tongue although not previously acquainted with each other voted together. An unconscious esprit-de-corps arose which banded them solidly against the other half of the jury. I do not think that either side noticed this fact but I am quite sure that the subtle influence of nativity and speech worked on them without their knowing it. Of course no court could foresee or suspect or avert this. I instance it only as an illustration of unconscious congregate influences on honest and conscientious but untrained minds.

I have been strongly impressed with the comparatively helpless situation of the defense in many cases of suit for damages especially

when the plaintiff is poor and the defendant in comparative affluence and still more especially when a corporation. Quite apart from the traditional attitude toward the so-called soulless corporation a class of circumstances may put the defendant at a great and unfair disadvantage.

The case of the plaintiff who slipped on a curbstone and claimed that a sunken brick pavement compelled her to so step on the curb as to slip, is in point here. The very fact that the photographs are handed about and continually referred to, that witnesses have seen that condition there for years, that the woman's leg was so sprained by her fall as to prevent her making her living as heretofore gradually works upon the minds of the jurors because no one can say that none of these things are so.

I remember seeing nothing very bad in the photographs at first but the incessant references to the lines of the picture (I now see) exaggerated in my own mind the dangers from such conditions at a crossing. Some of the jury were particular to say that they believed in discouraging the legal traffic in damage suits but they also believed that sidewalks should not be allowed to become a menace to the walking public. Small compensation was therefore agreed upon by the clumsy process of averaging the vote.

A few weeks later I went, out of curiosity, to see the place itself. I am quite confident that as a casual pedestrian the slight sinking of the bricks and the slope of the curbstone would never have attracted my notice. The photographs were in a sense true and in a sense untrue. The proportions of the street were distorted and the view-points were selected for a purpose. Much was made, at the trial, of the rounded curb which had been worn that way by the grating of heavy wheels against it on the corner. The rounding never looked bad to me on the photograph but as I think back to an objective view of my own mind during the trial, excusing the photograph's supposed untruth as being too small or perhaps not properly posed to show the real danger, I see how gradually I began to think against my real judgment and see untruly. And now in its very presence the stone itself looked no worse to me than did the photograph at first; and I am bound to wonder why if this pavement and curb were entirely to blame there are not such accidents going on all over the

city every day, for I notice that that pavement was relatively not dangerous or bad.

I am not quarrelling with the verdict in which I had a part. It was not very serious either way except as a matter of abstract justice. I am merely trying to show how much more those pictures, in conjunction with the strained reiterations of witnesses, counted for than they were really worth. The mind believed what was true in them because they were photographs and excused and apologized for what seemed untrue (but was really very true)—also because they were photographs.

In an article on "Photography and Crime" Mr. C. H. Claudy says:

> "Any capable photographer knows how to magnify or minimize certain parts of the perspective of any view. Thus, a long-focus, narrow-angle lens will give a totally different result from a wide-angle, short-focus lens. In a suit for damages because of obstructions left upon the street, for instance, a lawyer will have a photographer use the latter lens and stand close to the alleged obstructions. A pile of earth, particularly if photographed low, will appear very large in proportion to the vanishing perspective of the street. A natural-angle photograph, made with a ten-inch lens on a five-by-seven plate, will give a totally different idea of the size of the obstruction.
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> "Cracks in buildings, as evidence of the damage done by subway construction or sewer-laying, can not be brought before a jury; but photographs of them can be so used as evidence. A clever photographer, by manipulation of his illumination, so that one side of the crack throws a heavy shadow can make such fissures appear far larger than they really are. Pictures of hills, to show the locality of a runaway, can be made steep or flat according to how the camera is handled. It is not, therefore, necessary to resort to actual changing of the negative and print to make the camera deceptive, and more and more are our courts coming to understand this fact."

I have been startled several times with the seeming unevenness and bad brick-laying in a brick extension wall of my own house. In early summer the low afternoon sun throws long shadows lengthwise from irregularities in the brick quite unobservable at other times. A photograph of the wall at such a time might be shown as strong evidence that the wall had suffered some kind of disruption. Yet the fact is that it is finely and evenly laid.

No allegations of attempt to falsify in the case under consideration are here intended. It is true that in the pictures the little streets looked broad and fine but the defects of the pavement and the curb

were not exaggerated. The point is, that when photographs are shown in support of the verbal testimony even the discriminating mind is apt to be over-persuaded by the mere fact of pictures. Any seeming lack therefore on the part of the picture is subconsciously excused on the ground that a depression of two inches in a pavement is necessarily diminished to almost nothing in a photograph. Then the mind rebounds to an exaggeration of the truth notwithstanding the claim that the depression does not exceed two inches.

Manifestly, the defense has little show in such a case. He cannot prove that the plaintiff did not fall from this cause. His one witness denied the dangerous character of conditions and to us jurors this denial seemed fatuous and partisan. But when I saw the place itself I thought this witness more right than wrong—more true indeed to the moral fact than all the others.

I am quite sure that had the jury been taken in a body to the actual scene of this accident the outcome would have been different. I could scarcely believe my own eyes. I tried to slip on the curb as the plaintiff slipped because of the slightly sunken but not rough pavement, but I failed. True, I had rubber heels but true, also, the woman may have had suicidal "French heels." Of this we jurors had no knowledge but some of us thought of it. All the verbal testimony of many witnesses corroborated what the photograph was supposed to show. It did show lines and shadows but not danger. The witness said danger and the jury believed that the photographs showed it too. Doubtless, also, the degree of damage which the woman suffered became, sub-consciously in the jury mind, the measure of that danger. I see now, that the pictures did not prove danger —not relatively, at least, as I find pavements and curbs wherever I go as bad and worse but they do not seem to me dangerous. If the defendant was guilty of negligence, comparatively few property holders are not guilty.

7 This case has been reviewed at some length because of its illustrative values in pointing out how the mind shifts itself under the subtilties of "evidence" which is in reality no evidence, but which cannot be denied or assailed as untrue and cannot be easily ruled out.

It seems to me that with a knowledge of the psychology of the gradual winning of the juryman's mind in spite of his own better

thinking, appeal for retrial should have serious consideration by the judges. In such a case the defense in not weak because the lawyer is weak, not because the defense has not been properly worked up but because all the activity, all the pictoriality, all the interest, lies with the plaintiff. One woman slips; a hundred thousand do not slip; but they never come on the witness stand. Moreover, the mind assumes that unless the case were good no photographs would have been taken, as the risk of recoil would have been too great.

In cases where medical experts are called to testify lawyers are too much inclined to display their crammed knowledge of the anatomy and physiology of injured limbs. Direct and cross-examination in these cases are sometimes carried to absurd length and minuteness. It makes little difference to a jury how a nerve moves the muscle and how the life process itself produces movement. I am quite aware that some of these foolish professional displays are made with the hope of discrediting the opposite expert witness but as a rule they are wearisome and even ludicrous—and neither of these conditions helps the cause.

Whatever makes for straightforward simplicity counts for the jury's favor. It is then that the real evidence weighs at its true value. Of course there are jurymen who admire adroitness, shrewdness, cleverness, even craftiness in an attorney and are much influenced by that admiration rather than by the real merits of the case. But these very attainments or methods work the other way with many jurors; and the insolent brow-beating of witnesses or manifest effort to confuse and "rattle" a simple-minded and honest witness is pretty sure to awaken indignation in the jury and recoil on the parties indulging in that kind of practice. This indignation is no part of the evidence which jurors are sworn to decide the case upon but it goes for evidence as weight in the mental balance.

And on this point, when the court orders a specific verdict without consulting the mind of the jury, is it not virtually ordering possible perjury or, in effect, subornation? Seeing their liability to this kind of termination to their labors jurors sometimes grow lax or indignant, according to their temper. They become puppets either way and official "evidence" becomes of less moral moment in their service.

.In point here, is a paragraph from *Law Notes* (March, 1910):

> " Judge Caldwell who had served nearly 35 years on the bench of the Federal District and Circuit Courts said that trial by jury was guaranteed in the Constitution 'because the people knew the judges were poor judges of the facts' and that 'every day's experience confirms the wisdom of their action. Equally strong testimony has been given by some of the greatest judges this country has ever known,' . . . . How many self-respecting men will condescend to serve willingly on juries if they know the judge is likely to hold them up to public scorn because he disagrees with their unanimous opinion delivered under oath?"

Now let us add to this question the weight of the fact that the greater the intelligence and moral force of the juror the greater his antipathy to such an unjust service. And in his resentment lies the psyschological menace to his natural qualifications. And surely the lower grade of man is not to be preferred because of his being the more subservient.

Not having sufficiently investigated the claim of the incompetency of judges to judge of " facts " I make no comment on it—except that apriori grounds seem to me to favor it. But if it be true then many a case suffers (as indeed every juror knows) from the exclusion as well as the inclusion of testimony. If the juror is a better judge of " facts " than the judge is then the juror should have power to call for such facts as appear to him to bear on the case. I for one have heard witnesses choked off by the incessant objecting of attorneys until the testimony was squeezed dry of all that essence which gives to a story its true value. True, a witness may overcolor and may run into imaginings and expeditionary sallies of sentiment and statement and this freedom should be limited. Nevertheless, the dry skeleton of what the court calls " facts " is often as untrue by default of important facts as the overweighted story tends toward giving an untrue impression of the case.

The juror should not be submitted to the strain of shutting out what he heard ruled out by the judge as not being relevant or admissible as evidence. I remember hearing a jury debate the import of an offhand written promise to pay a large sum. A youthful juror reminded us that the judge had said that we could consider the oral testimony in such a case. At least half the jury disregarded the paper because the judge permitted the oral testimony to count. The

other half saw in the paper the most vital evidence not, however, because the judge admitted it but because it appealed to their sense of business honor. Another judge might have ruled it out entirely as it lacked some factors of a formal document. What is evidence to some is not evidence to all, and no line can be drawn for testimony. Should not jurors have some right to demand such information as seems to them to be evidence? The "rules of evidence" are sometimes as wooden as they are usually useful. The mind of the average jury is in danger of being befogged by the ins and outs of matter offered as testimony.

It is true that a jury has more power than it usually takes in examining witnesses or inquiring of the court. But that is in large degree because the juror feels his automatism and his incarceration. Many a juror would like to ask questions but he has not been invited and he is afraid of attitude. He works under threat and all penologists are agreed that timidity and fear under threat do not make for strong intitiative or moral control.

In no situation in life is what Bergson calls the "professional comic" more evident than in the court room. It is always conspicuous in convocations of the clergy, of physicians, and even of men of science. The professional comic is the all-enveloping rut and the discerning layman is usually the stone that throws the wheel out on to new ground. This is the value of the jury. The juror is a layman but unfortunately he is too much a strangled and manacled servant to have either a layman's self-respecting freedom or the self-imposed constrictions of professionalism. He is never quite himself because he is under duress involuntarily doing work of professional nicety—involving complex calculation and insight to human motives, a gift of interpretation, a sense of probability, the elimination of personal bias. He is physiologist, pathologist, physicist, psychologist, detective, financier, moralist, jurist. And he is only a lackey without personality.

It is comparatively seldom that the witness who is sworn to give the "whole truth" is permitted to do so. The juror sees the effort of counsel to prevent his getting hold of it. He notes how the wooden "rules of evidence" sometimes cut out a body of testimony, the

pores of which are juicy with the very quintessence of evidence. The keen juror, scenting the aroma, longs to tap or squeeze out the sap of truth. But who is he, forsooth, but a juryman?

A physician, speaking out of much experience as an expert witness, told his medical associates that it is not enough that the evidence which they might be called on to give should be the truth. This, indeed, he said, has little to do with it for it must agree with the lawyers' and the court's idea of what is evidence, which is sometimes quite another thing.

Meantime the poor juror is between the devil and the deep sea—between the professional battle to suppress facts and his own sense of essential truth; between his own real conscience and the artificially imposed conscience of the court. So long, therefore, as "the evidence" is prescribed by the court the juror ought not to be sworn to render verdict according to "the evidence," but without prejudice to strive to be just to all parties concerned. No other discipline is just to any party concerned.

There is strong tendency to reduce the employment of juries. The question is whether there could not be a better kind of jury, partaking at once of lay and of professional advantages. It would be perhaps a permanent board adequately paid, non political, smaller than our present jury, not bound by the rule of unanimity, having large authority in taking and using testimony, and treated with the dignity due to the upper officers of a court of justice. In other words the disciplinary irritants, drawbacks, indignities, coercion, threats and sources of indifference and personal bias should be reduced to the minimum. Only thus can the balances of the juror's mind work as freely as possible in the valuation of evidence—which evidence, in very truth is not limited to the sworn statements of witnesses or other facts of the testimony but grows out of the interpretation of experience and of human nature in the large. The system, whatever it is, should not indifferently permit or encourage self-defeat. Justice to the contending parties rests in no small degree on justice to the jury.

ON THE PRODUCTION OF AN ARTIFICAL HISS.

By E. B. TITCHENER.

(*Read November 6, 1914.*)

In *Nature* of May 29, 1913, Lord Rayleigh asked to be told "how to make an artificial hiss." I replied that, if Köhler's observations are reliable, "a Galton whistle, set for a tone of 8,400 v. d., will give a pure *s*."[1] Lord Rayleigh, however, was not impressed by the suggestion.[2]

It occurred to me that the question might be put to the test of experiment. The sound of a Galton whistle set for 8,400 v. d. might be imitated by the mouth, and a series of observations might be taken upon material composed partly of the natural (mouth) sounds and partly of the artificial (whistle) tones. If a listening observer were unable to distinguish between the two stimuli, and if the mouth-sound were shown, phonetically, to be a true hiss, then it would be proved that the whistle also gives an *s*, and Lord Rayleigh would be answered.

The experiment was more troublesome that I had anticipated; but I may say at once that it has been carried out, and with affirmative result.

We used an Edelmann-Galton whistle (No. 423) actuated by a rubber bulb.[3] Our first difficulty was to find a competent experimenter. For the sound of the whistle is clean-cut, uniform, so to say dogmatic. This very definite stimulus has to be duplicated by a certain setting of tongue and lips, and by voluntary regulation and

[1] *Nature*, July 3, 1913; W. Köhler, *Zeits. f. Psych.*, LXIV., 1913, 93.

[2] *Nature*, July 31, 1913.

[3] The bulb that comes with the instrument must soon be renewed. It may be worth while to point out that bulbs of white or grey sulphur-coated rubber should never be employed; the fine dust chokes the mouthpiece and plays havoc, *e. g.*, with terminal determinations. We use a black rubber that is slightly more flaccid than that furnished by Edelmann.

direction of a current of air. But not only are there gross differences in the mode of formation of the *s*-sound; there are also individual differences, due apparently to the arrangement of the teeth, the shape and size of the tongue, and so forth;[4] and beside these, there are differences in ability to maintain the sound begun, to hold it from fluctuation during its course. The sound that one emits, on first trying to imitate the whistle, may therefore be almost comically wrong,—broad, harsh, irregular, soft, wavery, instead of sharp and keen.

We presently found two experimenters, Mr. N. P. Stephens and Mr. P. T. Carson, who after practice were able in a large proportion of successive attempts to reproduce the sound of the whistle. Neither these nor the other volunteers whom we tried out could, however, imitate the sound obtained by the ordinary vigorous squeeze of the bulb, such a squeeze as one gives in determinations of the terminus. We therefore had recourse to a compression which, though sharp and definite, was still weaker than that by which the whistle is usually actuated. The difference between the mouth-sound and the whistle-sound given at full intensity is, so far as our observations go, that the latter is beady, intense, compact, while the former is broader, weaker, coarser. The compression which we used was, nevertheless, strong enough to yield clear dust-figures by the Kundt method.[5] No doubt, it varied somewhat, both in the experimental series and in the dust-figure determinations. But the hand-pressure becomes rather surprisingly even, with a little practice; and determinations made at different times by Dr. Foster varied only between the limits of $8{,}594 \pm 63$ v. d. and $8{,}522 \pm 27$ v. d. It is therefore certain that we were working in the near neighborhood of Köhler's optimal 8,400 v. d.

[4] See, *e. g.*, C. L. Merkel, "Physiologie der menschlichen Sprache," 1866, 186 ff., Taf. III.; G. H. von Meyer, "The Organs of Speech," 1884, 314f.; G. E. Sievers, "Grundzüge der Phonetik," 1885, 56 ff., 122 f.; O. Jespersen, "The Articulations of Speech Sounds," etc., 1889, 61 f., 87; H. Hoffmann, "Die Lautwissenschaft," etc., 1901, 62; W. Vietor, "Elemente der Phonetik," etc., 1887, 125 ff.; E. Seelmann, "Die Aussprache des Latein," etc., 1885, 245 f.; H. Sweet, "A Handbook of Phonetics," 1877, 33, 39 f.

[5] M. T. Edelmann, "Studien über die Erzeugung sehr hoher Töne, etc.," Drude's *Annalen*, II. [CCCVII.], 1900, 469 ff.

An ideal experimental series would now have consisted of equal numbers of mouth-sounds and whistle-sounds arranged in haphazard order. But the experimenters could not thus accurately reproduce the whistle-sound. If the series chanced to call for several mouth-sounds in succession, then the setting of the mouth could be maintained; but if mouth and whistle alternated, or if a single mouth-sound were to be given among several whistle-sounds, there was need of readjustment and possibility of initial failure. It seemed best that whenever the mouth-sound was obviously wrong, and when (as sometimes happened) the squeeze of the bulb was too light or too heavy, the experimenter should say: "Don't count that! Repeat!" and should simply try again. This procedure gave the observers a certain advantage; but we thought it preferable to a voluntary change or a further haphazard determination of the stimulus. The more successful of our two experimenters, Mr. Stephens, was obliged, even at his highest level of practice, to repeat the mouth-sound in 12 to 15 per cent. of the trials.

There was a further complication. The observers sat at a distance of not more than 1 m. from the source of sound; they declared that, if they were to judge discriminatingly, they must be as near as possible; and they tended to lean or move in toward the experimenter. The preliminary experiments showed that, under these conditions, their judgment might be influenced by secondary indications—the direction of the sound, the noise of breathing, of setting the mouth, even of the squeeze of the bulb, the noise of preparatory movements in general. Hence they were informed before the regular series began that these indications were not to be relied upon, but that the experimenter might in any given test make misleading preparations. In fact, 50 per cent. of the mouth-sounds were accompanied by noises of bulb and table, and 75 per cent. of the whistle-sounds by noises of breathing and mouth-setting. The numerical results and the introspective reports prove that this ruse was successful. The observers based their discriminations, for the most part, upon the temporal course and the "size" of the stimuli; the sound was judged to be "whistle" if it was hard, clear-cut, abrupt, and to be "mouth" if it was fluctuating, "trembly," soft, diffuse. Sometimes pitch was referred to (whistle higher), and sometimes

intensity (whistle louder). The number of confusions testifies that these differences were not very dependable.

The first series of experiments (July, 1914; Mr. Stephens, experimenter; Miss F. A. Bean, observer) consisted, as planned, of 70 mouth-sounds and 70 whistle-sounds taken in haphazard order. Aside from the disturbances to which I have referred, the results were:

	Whistle.	Mouth.
Whistle judged as	60	10
Mouth judged as	25	45

Mr. Stephens was at this date relatively unpractised, while Miss Bean had had extended practice in the discrimination of whistle-tones. The number of confusions (25 per cent. of the whole number of observations) was, evidently, large enough to warrant a continuation of the experiment.

Other series, made by Messrs. Stephens and Carson with other observers, brought results of the same numerical order; they need not be cited. I pass at once to the two final series made (August, 1914) by Mr. Stephens. The first comprised two part-series of 50 tests, each composed of 25 mouth-sounds and 25 whistle-sounds. The observer, Dr. W. S. Foster, knew the plan of the investigation, had himself tried to reproduce the whistle-tone by mouth, and had had recent and unusually extended practice in the discrimination of whistle-tones. The percentages of confusion were:

Whistle judged as mouth	18
Mouth judged as whistle	20

or an average confusion of 19 per cent.

In the second series, two part-series of 50 tests were composed, the one of 22 whistle and 28 mouth sounds, the other of 28 whistle and 22 mouth sounds. The observers, Dr. E. G. Boring, Dr. L. D. Boring and Dr. M. E. Goudge, sat together for the experiment. Dr. E. G. Boring had had a good deal of practice with the whistle, and the other observers had performed the regular laboratory experiments in which it is employed. All three were, however, given special practice (with knowledge) in the discrimination of the stimuli now to be used. The percentages of confusion were:

Observer.	Whistle Judged as Mouth.	Mouth Judged as Whistle.
E. G. B.	20	36
L. D. B.	45	38
M. E. G.	35	39

or an average confusion of 35.5 per cent.

There is, naturally, a tendency, on the part of the practised observers, to judge "mouth as whistle" more often than "whistle as mouth": the percentages are, for Miss Bean, 35.7 : 14.3, and for Dr. E. G. Boring, 36 : 20. Dr. Foster, who can hardly be deceived, gives approximately equal percentages of confusion; but in his case too the ratio 20 : 18 favors "mouth as whistle." The less practised observers, however, offset each other. I had expected a far greater preponderance of correct judgments of the whistle, *i. e.*, a lesser number of judgments of "whistle as mouth"; and I think that the percentages actually obtained speak well for the skill of the experimenter.

It remains to show that our mouth-sound was a hiss. Neither of the experimenters was versed in phonetics; but we asked them to observe and describe carefully the position of lips and tongue during imitation of the whistle-sound. Mr. Stephens writes:

"The position of the tongue is substantially, so far as I can judge, the same as that in which we produce the sound of the letter *s-s-s*. The sides of the tongue are so curled up that they rest against the inside of the upper teeth, on the sides. The middle of the tongue thus of course forms a hollow, up to the tip,—which very nearly touches the roof of the upper jaw just about a quarter-inch above the upper teeth . . . . For the production of a light hiss which is not to be heard loudly the tongue-muscles are semi-tightened as also are the muscles of the jaw and throat. The thin column of air which is forced lightly between the tip of the tongue and the point on the roof of the mouth makes production of sound. Teeth along sides and back are possibly 5 or 6 mm. apart, thus leaving plenty of opening for ejection of air. The lips stand a quarter-inch apart, with little or no drawing at the corners, for the light hiss. Lips, in the production of this sound, play little or no part; they merely are separated sufficiently so as not to interfere with air and sound. Unless they are well apart, however, they do interfere with the intensity and seeming pitch of the hiss."

This is a very fair amateur account of the production of a hiss; and if it is compared with the formula given, *e. g.*, by Jepersen, we

cannot doubt that Mr. Stephens was sounding an English *s*.[6] At the point where I have marked an omission, he draws a diagram which, with allowance made for amateur draughtmanship, is identical with the "[s] nach Bremer" of Jespersen's plate; it is needless to say that he had never opened Jespersen's book. Mr. Carson gives a very similar account, except that he appears to place the tip of his tongue a trifle further forward, and thus to approximate the German *s*. It is quite clear, then, that the experimenters were hissing.

So we have the artificial hiss that Lord Rayleigh asked for. It may be too weak for his purposes; and, more especially, it may be of too brief duration. We were able, however, to match the abrupt hiss of the experiments to a continuative hiss sounded by a second Edelmann whistle (No. 679) connected with the Whipple tanks: intensively, the match was only approximate; qualitatively, we regard it as fairly accurate.

For the qualitative determination we employed two methods. (1) The sound of whistle No. 423, actuated as in the experiments, was compared with three sounds from whistle No. 679 actuated by a regulated current of air from the tanks. These three sounds lay at what we supposed to be the point of equality with the sound of No. 423, at a pitch some 400 v. d. higher, and at a pitch some 400 v. d. lower. The three comparative pitches were intermixed in haphazard order; both time-orders were presented; and for the final series of observations we had the services of Professor H. P. Weld, a skilled musician as well as psychologist. (2) By a roundabout method of determination, which involved reliance on the Edelmann tables, we established the "identical" pitch of No. 679 as 8,430 v. d. Since Professor Weld's judgment made this pitch equal to or very slightly lower than the given pitch of No. 423, and since the error of our determination (provided always that Edelmann's tables are correct) can hardly have exceeded ± 100 v. d., we may assume that the two whistles gave very nearly the same *s*.

[6] O. Jespersen, "Lehrbuch der Phonetik," 1904, 34, 127 f. Mr. Stephens' use of the word "hiss" was spontaneous, not due to suggestion.

We were unable to determine the pitch of the continuative hiss by the Kundt dust-method; the lycopodium powder obstinately refused to move.

The accuracy of the Edelmann tables has been questioned by C. S. Myers ("On the Pitch of Galton Whistles," *Journ. of Physiol.*, XXVIII., 1902, 417 ff.). Edelmann does not give the m. v. of his scale readings; but it is possible that his technique is so accurate that the variation is minimal, or even that a single count suffices. Neither does he tell us how he compresses his bulb; it is probable that he uses some mechanical device which ensures a constant compression. We have ourselves made the following determinations with whistle No. 423 (temperature read as the mean of four thermometers):

(1) Ordinary vigorous squeeze, such as is employed in terminal determinations:
  Found from 5 trials with the dust-method.............. 8,897 ± 18 v. d.
  By Edelmann's table.................................. 8,775

(2) Weaker squeeze, used in our experiments:
  Found by dust-method................ 8,594 ± 63 v. d. to 8,522 ± 27 v. d.
  By Edelmann's tables + judgments of coincidence of tones 8,430

(3) Very violent squeeze, 10 trials by dust-method........ 9,046 ± 71 v. d.

It is clear that Edelmann uses a "normal" compression, of the same order as that which an experimenter naturally employs for terminal tests. Random determinations of our two whistles at different points of the scale, with the ordinary vigorous squeeze, agree within about 100 v. d. with the Edelmann tables.

We have had but little experience with continuous tones under change of water-pressure; but we find, so far, that the pitch of our whistles does not alter appreciably within the limits of 90 to 160 mm. of pressure.

While, then, we do not question the accuracy of Myers' determinations, we think that there is no need either to doubt the reliability of the Edelmann whistle under "normal" conditions.

MINUTES

MINUTES.

Stated Meeting January 2, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Invitations were received:

From La Reale Accademia de Ciencias y Artes de Barcelona to be represented at the celebration of the 150th anniversary of its foundation on the 18th, 19th and 20th of January next.

From the Regents of the University of the State of New York to be represented at the Inauguration of John Huston Finley as President of the University and Commissioner of Education of the State of New York, at Albany on January 2d, 1914.

The list of donations to the library was laid on the table and thanks were ordered for them.

The decease was announced of James MacAlister, A.M., LL.D., at sea on December 11, 1913; æt. 74.

Prof. E. G. Conklin read a paper on "Some Facts and Factors of Development"; which was discussed by Doctors Donaldson and Dercum, and Prof. Conklin.

The judges of the annual election of officers and councillors held on this day between the hours of two and five in the afternoon, reported that the following named members, according to the laws, regulations and ordinances of the Society, were elected to be the officers for the ensuing year:

President.

William W. Keen.

Vice-Presidents.

William B. Scott,
Albert A. Michelson,
Edward C. Pickering.

Secretaries.

I. Minis Hays,
Arthur W. Goodspeed,
Amos P. Brown,
Harry F. Keller.

Curators.

Charles L. Doolittle,
William P. Wilson,
Leslie W. Miller.

Treasurer.

Henry LaBarre Jayne.

Councillors.

(To serve for three years.)
Samuel Dickson,
Ernest W. Brown,
Morris Jastrow, Jr.,
Arthur Gordon Webster.

Stated Meeting February 6, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Mr. Samuel Rea, a newly elected member, subscribed the Laws and was admitted into the Society.

The decease was announced of the following members:

At St. Petersburg on January 2/15, 1914, Théodose Tschernyscheff, Director of the Geological Survey of Russia; æt. 67.

At Philadelphia on January 4, 1914, S. Weir Mitchell, M.D., LL.D.; æt. 84.

At Plattsburgh, N. Y., on January 7, 1914, William D. Marks; æt. 65.

At Cambridge, Mass., on January 14, 1914, Benjamin Osgood Peirce, Ph.D.; æt. 60.

At London on January 24, 1914, Sir David Gill, K.C.B.; æt. 70.

At Philadelphia on February 1, 1914, Charles E. Dana, C.E., æt. 71.

Dr. P. B. Hawk read a paper on "The Relationship of Water to Certain Life Processes, and More Especially to Nutrition"; which was discussed by Dr. Brubaker, Prof. Kraemer, Dr. Dercum, Prof. Keller and Mr. Carson.

Stated Meeting March 6, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Invitations were received:

From the Deutsche Shakespeare Gesellschaft to participate in the celebration of the 50th Anniversary of its founding on April 22 to 24, 1914.

From the Premier Congrès de Police Judiciare Internationale to participate in the Congress to be held at Monaco on April 14 to 20, 1914.

From the 19th International Congress of Americanists to be held at Washington October 5 to 10, 1914, to be represented thereat.

The decease was announced of:

Edwin J. Houston, Ph.D., at Philadelphia, on March 1, 1914; æt. 67.

Stuart Wood, Esq., at Philadelphia, on March 2, 1914; æt. 62.

Dr. Samuel W. Stratton read a paper on "Standards of Quality;" which was discussed by Dr. Donaldson, Dr. Keller, Mr. Day and Mr. F. Rawle.

Stated Meeting April 3, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

A letter was received from Senatore Giovanni Celoria expressing the grateful thanks of the Committee for 283.25 lire contributed by the members of this Society as a subscription to the Giovanni Schiaparelli Memorial.

The decease was announced of:

Edward S. Holden, A.M., LL.D., at West Point on March 16th, 1914; æt. 68.

Sir John Murray, K.C.B., Sc.D., LL.D., at Edinburgh on March 16th, 1914; æt. 73.

The following papers were read:

"Explorations in the Hudson Bay Regions with references to Unusual Topographic and Hydrographic Features and Mineral Deposits," by Mr. Ambrose E. Lehman; which was discussed by Mr. Willcox, Mr. Garrison and Mr. DuBois.

"On Psychology as the Behaviorist Views It," by E. B. Titchener, Ph.D., Sc.D., LL.D.

Stated General Meeting April 23, 24 and 25, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Thursday, April 23—Opening Session.

The decease was announced of George William Hill, Sc.D., LL.D., at West Nyack, N. Y., on April 18, 1914; æt. 76.

The following papers were read:

"The Physical Cause of the Unsymmetrical Equilibrium of the Earth Between the Land and Water Hemispheres, with a Theorem on the Attraction of the Terrestrial Spheroid," by T. J. J. See, Ph.D., U. S. Naval Observatory, Mare Island, California.

"Some Observations on the Psychology of Juries and Jurors," by Patterson DuBois, Esq., of Philadelphia.

"Factors of Influence in the Origin and Circulation of the Cerebro-Spinal Fluid," by Charles H. Frazier, M.D., Professor of Clinical Surgery, University of Pennsylvania. Discussed by Dr. Crile.

"Aspects and Methods of the Study of the Mechanism of the Heart Beats," by Alfred E. Cohn, A.B., M.D., Associate in Medicine, Rockefeller Institute for Medical Resarch, New York. (Introduced by Dr. Keen.) Discussed by Dr. Keen.

"The Kinetic System," by George W. Crile, M.D., Professor of Clinical Surgery, Western Reserve University, Cleveland. Discussed by Dr. Keen and Dr. W. P. Wilson.

"The Hereditary Basis of Certain Emotional States," by Charles

B. Davenport, A.M., Ph.D., Director of Station for Experimental Evolution (Carnegie Institution), Cold Spring Harbor, New York.

"Syriac Socrates—A Study in Syrian Philosophy," by W. Romaine Newbold, Ph.D., Professor of Philosophy, University of Pennsylvania.

"The Evolution of Pine Barren Plants," by John W. Harshberger, Ph.D., Professor of Botany, University of Pennsylvania.

"Segretion of 'Unit Characters' in the Zygote of Oenothera with Twin and Triplet Hybrids in the First Generation," by George Francis Atkinson, Ph.D., Professor of Botany, Cornell University. Discussed by Prof. Bradley M. Davis and Prof Kraemer.

"The Vegetation of the Sargasso Sea," by William G. Farlow, Ph.D., LL.D., Professor of Cryptogamic Botany, Harvard University. Discussed by Prof. Harshberger, Prof. Atkinson, and Prof. Farlow.

"A New Type of Oak for America," by William Trelease, Sc.D., LL.D.

Friday, April 24.

Executive Session—9:30 o'clock.

William W. Keen, M.D., LL.D., President, in the Chair.

The proceedings of the officers and council were submitted and the list of nominations for membership recommended for election this year was reported.

The following resolution recommended by the officers and council was adopted:

That a Committee of eight members shall be appointed by the president at the first executive session of the general meeting in every year to nominate officers and councillors for the succeeding year. The president shall be ex-officio a member of this committee, but shall have no vote except in case of a tie. This committee shall report at the stated meeting on the first Friday in December and its

report shall be regarded as nominations duly made for the respective offices. But nothing herein contained shall be considered as restricting the right of any individual member to make nominations as provided in the Laws.

Members are invited to make to this Committee suggestions of appropriate nominations and it shall be its duty to give full consideration to the same.

The President thereupon appointed the following members to constitute the Committee: Dr. Hays, Prof. E. W. Brown, Prof. Trelease, Dr. R. S. Woodward, Hon. Charlemagne Tower, Dr. Donaldson, Prof. Gummere, Prof. Farlow.

Morning Session—9:35 o'clock.

ALBERT A. MICHELSON, Ph.D., Sc.D., LL.D., F.R.S.

Vice-President, in the Chair.

The following papers were read:

"Phase Changes Produced by High Pressures," by Percy W. Bridgman, Instructor in Physics in the Jefferson Physical Laboratory, Harvard University. (Introduced by Prof. Goodspeed.) Discussed by Professors Pickering, Hobbs, Bogert, Noyes and Michelson.

"The Influence of Atmospheric Pressure on the Forced Convection of Heat from Thin Electric Conducting Wires," by Arthur E. Kennelly, Sc.D., Professor of Electrical Engineering, Harvard University.

"Some New Tests of Quantum Theory and a Direct Determination of *h*," by Robert Andrews Millikan, A.M., Ph.D., Professor of Physics, University of Chicago. (Introduced by Prof. Goodspeed.) Discussed by Prof. Michelson.

Discussion of "A Kinetic Theory of Gravitation": (1) Gravitation is Due to Intrinsic Energy of the Ether; (2) Transmission of Gravitation Cannot be Instantaneous, by Charles F. Brush, Ph.D., Sc.D., LL.D., of Cleveland. Discussed by Prof. Nipher.

"Behavior of Metals and Other Substances Under Stress Near the Rupture Point," by A. A. Michelson, Ph.D., LL.D., Professor of Physics, University of Chicago. Discussed by Prof. E. W. Brown, Mr. Bridgman, and Mr. Brush.

"On Highly Radio-Active Solutions," by William Duane, A.M., Ph.D., Assistant Professor of Physics and Research Fellow of the Cancer Commission, Harvard University. (Introduced by Prof. Goodspeed.) Discussed by Mr. Brush and Dr. Donaldson.

"Some Further Considerations in the Development of the Electron Conception of Valence," by K. G. Falk, of the Harriman Research Laboratory, Roosevelt Hospital, New York. (Introduced by Prof. Bogert).

"The Valence of Nitrogen in Ammonium Salts," by William Albert Noyes, Ph.D., LL.D., Professor of Chemistry, University of Illinois, and R. S. Potter. (Introduced by Prof. H. C. Jones.)

"Determination of the True Atomic Weight of Radium," by Gustavus Hinrichs, of St. Louis.

Afternoon Session—2 o'clock.

EDWARD S. PICKERING, D.Sc., LL.D., F.R.S.,

Vice-President, in the Chair.

Dr. Cyrus Adler in presenting a portrait of the late Samuel Pierpont Langley, LL.D., a former Vice-President of the Society, spoke as follows:

On behalf of a number of members of the Society I have the honor to present a portrait of Samuel Pierpont Langley, a former member and Vice President of the American Philosophical Society.

Mr. Langley, the third Secretary of the Smithsonian Institution, was a man of national and international fame which rested primarily upon his epoch making researches in solar physics. All of the recognition which came to him was based upon his discoveries in physics and astronomy. But he was also a pioneer in another field, being the first distinguished man of science to devote himself to the

subject of aerial navigation, at a time when this was not considered within the realm of scientific study. The meré fact that a man of his reputation and position gave serious attention to this important subject lent it an impetus and standing which it would not have otherwise received for many years and therefore greatly advanced the development of this science and art. But he did more than give an impetus, for he not only discovered principles of prime importance in connection with aerodynamics, but was the first to produce a machine heavier than air, supported and propelled by its own engine and possessed of no extraneous or lifting power which actually made an independent flight.

The first flight of a heavier than air machine which ever occurred took place over the Potomac River on May 6, 1896 and was succeeded by numerous other flights of various models, which he built, all of the monoplane type.

He had received honorary degrees from Oxford and Cambridge Universities in England and from Harvard, Michigan, Princeton and Wisconsin in the United States. Medals were awarded him by the National Academy of Sciences, the Royal Society of London, the American Academy of Arts and Sciences, the Institute of France and the Astronomical Society of France and he was a member or correspondent of all of these and many other learned Societies including the Academia dei Lincei of Rome.

He had an especial affection for the American Philosophical Society, one of the few organizations in which he accepted an office.

In addition to these great achievements, Mr. Langley was a man of wide culture and of deep sympathy and insight. That I was permitted to enjoy his friendship was one of the most profoundly valued and touching experiences of my life.

[The donors are Messrs. Cyrus Adler, Carl Barus, L. A. Bauer, Alex. Graham Bell, John A. Brashear, George F. Edmunds, George E. Hale, David Jayne Hill, George Gray, T. C. Mendenhall, Charles E. Munroe, Edward L. Nichols, Richard Olney, Henry Fairfield Osborn, Edward C. Pickering, Raphael Pumpelly, Edward B. Rosa, Frank Schlesinger, Samuel W. Stratton, Mayer Sulzberger, Elihu Thomson, Otto H. Tittmann, Charles D. Walcott, Andrew D. White and Robert S. Woodward.]

VICE-PRESIDENT PICKERING in accepting the portrait, said:

My acquaintance with Samuel Pierpont Langley goes back to the winter of 1870, when we crossed the ocean together to observe the total eclipse of the sun, in Spain. We maintained an unbroken friendship until his death, nearly forty years later. As a young man he was enthusiastic, and full of hope for the future. When placed in charge of the observatory at Pittsburgh, he found that the smoke in the atmosphere rendered stellar observations difficult. He therefore selected the sun as his object for study, since the smoke by cutting off the heat, rendered the air more steady. A skillful draughtsman, his drawing of that complicated object, a large sunspot, is probably the best ever made. In accepting the position of secretary of the Smithsonian Institution, he stipulated that he should be enabled to continue his scientific investigations. This led to the establishment of the astrophysical observatory, which has continued and extended his work to the present time. He devoted many years to the construction and improvement of the bolometer, one of the most delicate devices for measuring heat, and a most difficult instrument to adjust and use. For many years, the question of artificial flight had an absorbing interest for him. His investigations were long and laborious, and finally he attained success with a small model. When constructing a larger instrument, his sensitiveness induced him to avoid publicity, thus greatly annoying those whose business it is to keep the public informed of the latest news. They had their revenge when a misplaced nail in his launching apparatus ruined his aeroplane on its trial trip, and the subsequent ridicule and criticism saddened his last days, and shortened his life. The success of aerial navigation is largely due to his work, which has only received the credit it deserves since his death.

Langley, by his devotion to the advancement of human knowledge, well deserves a place among those whose portraits adorn these walls, and in the name of the American Philosophical Society held at Philadelphia for Promoting Useful Knowledge, I accept this portrait and extend grateful acknowledgments to the donors.

The following papers were read:

"The Magnetic Phenomena of Sun-spots."

"The General Magnetic Field of the Sun." (Illustrated with lantern slides.) By George E. Hale, Ph.D., LL.D., F.R.S., Director of the Solar Observatory of the Carnegie Institution at Mt. Wilson, Cal.

"On the Colors of the Stars in the Cluster M 13," by Edward E. Barnard, Sc.D., LL.D., Astronomer of the Yerkes Observatory, Williams Bay, Wis.

"The Use of a Photographic Doublet in Cataloguing the Position of Stars," by Frank Schlesinger, M.A., Ph.D., Director of the Allegheny Observatory, Allegheny Pa. Discussed by Prof. Pickering.

"The Distribution in Space of 90 Eclipsing Stars," by Henry Norris Russell, Ph.D., Professor of Astronomy, Princeton University.

"The Eclipsing variable Stars ψ Orionis and 88 d Tauri," by Harlow Shapley, Ph.D., of Princeton University Observatory. (Introduced by Prof. H. N. Russell.)

"Some Features of The Moon's Motion and a Problem in Isostasy," by Ernest W. Brown, M.A., Sc.D., F.R.S., Professor of Mathematics, Yale University.

"The United States as a Factor in World Politics," by Leo S. Rowe, Ph.D., LL.D., Professor of Political Science, University of Pennsylvania.

"A Sumerian Nature Hymn from Nippur, of the Time of the Dynasty of Agade, 2800–2600 B. C.," by George A. Barton, Ph.D., Professor of Biblical Literature, Bryn Mawr College.

Evening Session—8:15 o'clock.

Arthur L. Day, Ph.D., Director of the Geophysical Laboratory of the Carnegie Institution of Washington, gave an illustrated lecture on "Some Observations of the Volcano Kilauea in Action."

Saturday, April 25.

Executive Session—9:30 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Prof. George F. Atkinson and Prof. Charles Edwin Bennett, recently elected members, subscribed the Laws and were admitted into the Society.

Pending nominations for membership were read and spoken to.

Mr. J. Edward Whitfield and Dr. James McKeen Cattell were appointed tellers of election and the Society proceeded to ballot for members.

The tellers of election reported that the following nominees had been elected to membership:

Residents of the United States.

Charles Greeley Abbot, S.B., Washington.
James Wilson Bright, Ph.D., LL.D., Litt.D., Baltimore.
Bradley Moore Davis, A.M., Ph.D., Philadelphia.
Thomas McCrae, A.B., M.D., Philadelphia.
William Diller Matthew, A.M., Ph.D., New York.
Alfred Goldsborough Mayer, Ph.D., M.E., Washington.
Samuel Jones Meltzer, M.D., LL.D., New York.
John Campbell Merriam, B.S., Ph.D., Berkeley, Cal.
Robert Andrews Millikan, A.M., Ph.D., Chicago.
William Albert Noyes, Ph.D., LL.D., Urbana, Ill.
Stewart Paton, M.D., Princeton.
Richard Mills Pearce, Jr., M.D., Philadelphia.
Palmer Chamberlaine Ricketts, C.E., LL.D., Troy.
Harold A. Wilson, M.A., D.Sc., F.R.S., Houston.
Frederick Eugene Wright, Ph.D., Washington.

Foreign Residents.

Shibasaburo Kitasato, M.D., Tokyo.
Heike Kamerlingh Onnes, Ph.D., Leyden.
Vito Volterra, Sc.D., Ph.D., Rome.

Morning Session—10 o'clock.

William B. Scott, Sc.D., LL.D., Vice-President, in the Chair.

The following papers were read:

"Primary Cambrian Manganese Deposits of Newfoundland," by Nelson C. Dale, Fellow, Princeton University. (Introduced by Prof. W. B. Scott.)

"Geology of the Wabana Iron Ores of Newfoundland," by Albert O. Hayes, Fellow, Princeton University. (Introduced by Prof. W. B. Scott.)

"Hewettite, Metahewettite and Pascoite, Hydrous Calcium Vanadates," by W. F. Hillebrand, Ph.D., H. E. Merwin and Frederick E. Wright, Ph.D., of U. S. Geological Survey.

"The Relations of Isostasy to a Zone of Weakness—the Asthenosphere," by Joseph Barrell, Ph.D., Professor of Structural Geology, Yale University. (Introduced by Prof. Charles Schuchert.)

"Evidence for a Pulsational Change of Climate in the Libyan Desert," by William H. Hobbs, Ph.D., Professor of Geology, University of Michigan.

"The Cretaceous-Tertiary Boundary in the Rocky Mountain Region," by F. H. Knowlton, U. S. Geological Survey. (Introduced by Prof. John M. Clarke.) Discussed by Prof. W. B. Scott.

"The Geologic and Biologic Results of a Study of the Tertiary Floras of Southeastern North America," by Edward W. Berry, Associate Professor of Paleontology, Johns Hopkins University. (Introduced by Prof. William B. Clarke.) Discussed by Prof. W. B. Scott.

"On Multiple Treatment of One and the Same Story 'Motif,'" by Maurice Bloomfield, Ph.D., LL.D., Professor of Sanskrit, Johns Hopkins University.

"Some Biblical Miracles," by Paul Haupt, Ph.D., LL.D., Professor of Semitic Philology, Johns Hopkins University.

"The Sumerian Pronunciation of the Name 'Ninib' as the Chief Deity of Umma," by Alfred T. Clay, Ph.D., Laffan

Professor of Assyriology and Babylonian Literature, Yale University.

"Panama Tolls and Tonnage Rules," by Emory R. Johnson, Ph.D., Professor of Transportation and Commerce, University of Pennsylvania.

"Passamaquoddy Morphology," by J. Dyneley Prince, A.B., Ph.D., Professor of Semitic Languages, Columbia University, New York.

Afternoon Session—2 o'clock.

William W. Keen, M.D., LL.D., President, in the Chair.

Prof. William Albert Noyes, of Urbana, Ill., and Prof. Bradley Moore Davis, of Philadelphia, newly elected members, subscribed the Laws and were admitted into the Society.

Dr. William G. Farlow unveiled a Wedgwood medallion portrait of the late Sir Joseph Dalton Hooker, O.M., G.C.S.I., C.B. and spoke as follows:

Today we are so fortunate as to be able to add a medallion of one of the world's great botanists to the already large number of memorials of distinguished men which adorn this Hall and give it a dignity which is justly envied by other scientific societies in this country. Joseph Dalton Hooker, the more distinguished son of a distinguished father, was born in Halesworth, Suffolk, England, in 1817 and, retaining his scientific activity until the last, died at Sunningdale in 1911, a record very rarely equalled.

When four years of age his father, Sir William Hooker, removed to Glasgow, where he had been appointed Professor of Botany in the University, so that from his early childhood, the son was placed in surroundings which naturally pointed to botany as his life work. While a student of medicine, Hooker had the opportunity of reading the proofs of Darwin's "Voyage of the Beagle" which aroused in him an intense desire to travel. This desire was fortunately soon gratified, for immediately after receiving the degree of Doctor of Medicine in 1839, he was appointed assistant surgeon and botanist to the *Erebus* under the command of Sir James Ross, then about to start on his memorable voyage to the Antarctic regions.

On his return in 1843 Hooker made his home at Kew where his father had been appointed director of the Royal Gardens. He was appointed assistant director in 1855 and, on the death of his father in 1865, director, which position he held till his retirement twenty years later. We always think of Hooker as at Kew. It was there, aided by the large collections formed in great part by his father and himself, that he finished his different floras; there that he brought to perfection the Garden which had been raised by his father from insignificance to be the leading botanical garden of the world; there that many American botanists were received with a cordiality doubly welcome because they were encouraged by his sympathy and aided by his advice.

Hooker was undoubtedly the leading botanical systematist of his day. For this branch of botany he not only had great natural ability, but he also had opportunities for studying in the field the floras of distant and little-explored regions such as few trained botanists have had. Besides his Antarctic voyage, when he visited New Zealand and Tasmania as well as more southern regions, he spent the years 1848 to 1851 in an exploration of the Himalayas in company with Thomas Thomson,—an expedition involving great hardships among hostile people, but rich in results, and later he made trips to Palestine and Morocco. On his last long journey in 1877, he travelled with his old friend, Asa Gray, among the Rocky Mountains and in California.

On this occasion we need not consider in detail Hooker's various descriptive works on the floras of the countries he had visited, nor works like the great "Genera Plantarum," written in collaboration with Bentham, technical systematic treatises belonging to the classics of botany. Let us recall rather those qualities of Hooker which made him more than a systematist, which entitled him to rank with Darwin, Wallace, Lyall and Huxley in the brilliant group of naturalists which has never been surpassed, if it has ever been equalled, in any other country. Like Darwin, Hooker began his botanical career as an explorer of remote regions. The delightful account of the "Voyage of the Beagle" has its counterpart in the "Himalayan Journals" of Hooker. In both we recognize the fact that the

authors were something more than interesting relators of what they had seen. To them biological facts were only significant as indicating so many steps in the sequence of cause and effect. The genius of Darwin was manifested in his ability to see clearly in the beginning of his career the true direction in which the facts he had observed pointed, so that his lifework was unified, one step leading inevitably to another in the development of a great theory. It was much the same with Hooker. The writings which mark him as a philosophical botanist are the "Introductory Essay to the Flora of Tasmania"; the "Essay on the Distribution of Arctic Plants"; the "Discourse on Insular Floras"; the address at York on "Geographical Distribution," and the "Essay on the Vegetation of India," publications extending over a period of forty years.

The study of plant distribution involving a consideration of the geological phenomena which could account for it, and also of the question as to the effect of altered environment in modifying the characters of plants, naturally led to the fundamental question: What are Species and what are Varieties? One who, like Hooker, was master of the facts and without prejudice, could not fail to recognize that species are not fixed creations, but transitional stages in the progress of evolution. Hooker was a Darwinian even before the appearance of the "Origin of Species." It has been said with truth that, with the exception of Wallace, Hooker was the first adherent of Darwin in his views on evolution. How much that means is hardly realized at the present day. With us the question is not whether there is such a thing as evolution in plants and animals. We accept evolution as a fact, and, if there be any question, it is as to whether the explanation of the mode of its operation as presented by Darwin was satisfactory in all its details. In 1859, however, the date of the publication of the "Origin of Species," and for a considerable number of years later it required a good deal of courage as well as an unbiased mind for anyone, especially for an Englishman, to declare his assent to the revolutionary views advanced by Darwin.

In closing I may be permitted to repeat the words describing the position of Hooker among botanists on the occasion of the presentation to him of the Linnean gold medal at Stockholm in 1907.

"By scientific expeditions to many different parts of the world he has revealed the secrets of their vegetation. His extraordinary experience embraces both the nature of tropical India as also the subtropical and temperate climates, as well as of the cold antarctic regions. The contents of his floristic works are therefore exceedingly rich. He has furthermore enriched botany by splendid works in other departments of this science, for instance concerning the geographical distribution of plants, their classification and other matters."

I have the honor of unveiling the medallion of Sir Joseph Dalton Hooker, the energetic explorer, the eminent systematist, the distinguished investigator of the problem of plant evolution.

The following papers were read:

"The Burgess Shale Fauna of the Canadian Rockies," by Charles D. Walcott, Ph.D., Sc.D., LL.D., Secretary of the Smithsonian Institution, Washington.

"Summary of Researches, Department of Terrestrial Magnetism, 1904–14." (Illustrated.) By Louis A. Bauer, Ph.D., D.Sc., Director of the Department of Terrestrial Magnetism of the Carnegie Institution, Washington, D. C. Discussed by Prof. Pickering.

Symposium on Physics and Chemistry of Protoplasm:

"The Germ Plasm as a Stereochemic System," by Edward T. Reichert, M.D., Prof. Physiology in Univ. of Penna. (Introduced by Dr. Keen.)

"Arrangement and Distribution of Substances in the Cell," by Edwin Grant Conklin, Ph.D., Sc.D., Professor of Zoology at Princeton University.

"Vital Staining of Protoplasm," by Herbert McLean Evans, M.D., Associate Professor of Anatomy, Johns Hopkins University. (Introduced by Prof. Piersol.)

"The Physical State of Protoplasm," by G. L. Kite, M.D., Ph.D., Phipps Institute, Philadelphia. (Introduced by Prof. McClung.)

"The Physico-Chemical Organization of the Cell," by Lawrence J. Henderson, A.B., M.D., Assistant Professor of Biological Chemistry, Harvard University. (Introduced by Dr. H. F. Keller.)

Stated Meeting May 1, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Dr. Thomas McCrae, of Philadelphia, a newly elected member, subscribed the Laws and was admitted into the Society.

Letters accepting membership were received from:

Charles Greeley Abbot, S.B., Washington.
Bradley Moore Davis, A.M., Ph.D., Philadelphia.
Thomas McCrae, A.B., M.D., Philadelphia.
Samuel James Meltzer, M.D., LL.D., New York.
William Albert Noyes, Ph.D., LL.D., Urbana, Ill.
Stewart Paton, M.D., Princeton.
Richard Mills Pearce, Jr., M.D., Philadelphia.
Palmer Chamberlaine Ricketts, C.E., LL.D., Troy.
Frederick Eugene Wright, Ph.D., Washington.

The list of donations to the library was laid upon the table and thanks were ordered for them.

The decease was announced of George F. Baer, at Philadelphia, on April 26, 1914, in the 72d year of his age.

Prof. J. Russell Smith read a paper on "Tree Breeding with Relation to Conservation and the Food Supply," which was discussed by Prof. Bradley M. Davis and Dr. Keen.

Hon. Charlemagne Tower, Chairman, presented and read at length the report of the Committee on the Date of Origin of the Society.

On motion, by unanimous vote, the report was accepted; the year 1727 was declared to be the date of foundation of the Society, in accordance with the finding of the committee; and the committee was discharged with the thanks of the Society for its exhaustive report.

Stated Meeting October 2, 1914.

WILLIAM W. KEEN, M.D., LL.D., President in the Chair.

Dr. Richard Mills Pearce, a newly elected member, subscribed the Laws and was admitted into the Society.

Letters accepting membership were received from:

James Wilson Bright, Ph.D., LL.D., Litt.D., Baltimore.

William Diller Matthew, A.M., Ph.D., New York.
Alfred Goldsborough Mayer, Ph.D., M.E., Washington.
John Campbell Merriam, B.S., Ph.D., Berkeley.
Robert Andrews Millikan, A.M., Ph.D., Chicago.
Harold A. Wilson, M.A., D.Sc., F.R.S., Houston.
Shibasaburo Kitasato, M.D., Tokyo.
Heike Kamerlingh Onnes, Ph.D., Leyden.
Vito Volterra, Sc.D., Ph.D., Rome.

Invitations were received:

From the Ohio State Archaeological and Historical Society, to be represented at the dedication of its Museum and Library Building, at Columbus, on May 30th.

From the University of Missouri, to be represented at the 75th Anniversary of its founding on June 3d.

The decease was announced of the following members:

Edward Suess, Ph.D., at Vienna, on April 29, 1914, æt. 73.

William Aldis Wright, LL.D., D.C.L., Litt.D., at London, on May 19, 1914.

John Robert Sittlington Sterrett, Ph.D., LL.D., at Ithaca, N. Y., on June 16, 1914, æt. 63.

Frederick William True, M.S., LL.D., at Washington, on June 25, 1914, æt. 56.

John Barnard Pearse, at Roxbury, Mass., on August 24, 1914, æt. 72.

Morris Longstreth, A.M., M.D., at Barcelona, Spain, on Sept. 19, 1914, æt. 68.

Special Meeting October 30, 1914.

WILLIAM W. KEEN, M.D., LL.D., President in the Chair.

A paper was read on "A new Means of Studying Submarine Animal and Vegetable Life," illustrated by moving pictures of tropical deep sea flora and fauna.

Stated Meeting November 6, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The decease of the following members was announced:

Léon de Rosny, at Fontenay-aux-Roses (Seine), on August 28, 1914, æt. 78.

Theodore Nicholas Gill, M.D., Ph.D., at Washington, on September 25, 1914, æt. 77.

The following papers were presented:

"On Wireless Longitude Determination," by Eric Doolittle. Discussed by Professor C. L. Doolittle, Professor Snyder, Mr. Mitchell and Professor Miller.

"On the Production of an Artificial Hiss," by E. B. Titchener, Ph.D., D.Sc., LL.D.

Stated Meeting December 4th, 1914.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

An invitation was received from the Chairman of the 11th Annual Conference of Historical Societies to be held in Chicago in connection with and as part of the Thirtieth Annual Meeting of the American Historical Association, December 28 to 31, to participate in the conference by appointing delegates.

The decease was announced of

August Weismann, D.Ph., D.C.L., at Freiburg on November 5, 1914, æt. 80.

Charles Sedgwick Minot, M.D., Sc.D., LL.D., at Boston on November 19, 1914. æt. 61.

Alfred Thayer Mahan, LL.D., D.C.L., Rear Admiral U.S.N, at Washington on December 1, 1914. æt. 74.

Dr. John Mason Clarke of Albany read a paper on "The Magdalen Islands—a Relict Archipelago," which was discussed by Mr. Willcox and Prof. Pilsbry.

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PHILADELPHIA

THE AMERICAN PHILOSOPHICAL SOCIETY

104 SOUTH FIFTH STREET

1914

American Philosophical Society

General Meeting—April 22-24, 1915

The General Meeting of 1915 will be held on April 22nd to 24th, beginning at 2 p. m. on Thursday, April 22nd.

Members desiring to present papers are requested to send to the Secretaries, at as early a date as practicable, and not later than March 3, 1915, the titles of these papers, so that they may be announced in the final programme which will be issued immediately thereafter, and which will give in detail the arrangements for the meeting.

Owing to the embarrassment heretofore caused in a crowded programme by the receipt of titles at a very late date, the Committee of Arrangements announces, as a tentative plan, that additional papers can only be inserted in the *final* programme as there appears to be probable time for their presentation.

The Publication Committee, under the rules of the Society, will arrange for the immediate publication of the papers presented.

I. MINIS HAYS
ARTHUR W. GOODSPEED
AMOS P. BROWN
HARRY F. KELLER
Secretaries.

Members who have not as yet sent their photographs to the Society will confer a favor by so doing; cabinet size preferred.

It is requested that all correspondence be addressed

To the Secretaries of the
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MAGELLANIC PREMIUM

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1915

THE AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA, FOR PROMOTING USEFUL KNOWLEDGE

ANNOUNCES THAT IN

DECEMBER, 1915

IT WILL AWARD ITS

MAGELLANIC GOLD MEDAL

TO THE AUTHOR OF THE BEST DISCOVERY, OR MOST USEFUL INVENTION, RELATING TO NAVIGATION, ASTRONOMY, OR NATURAL PHILOSOPHY (MERE NATURAL HISTORY ONLY EXCEPTED) UNDER THE FOLLOWING CONDITIONS :

1. The candidate shall, on or before November 1, 1915, deliver free of postage or other charges, his discovery, invention or improvement, addressed to the President of the American Philosophical Society, No. 104 South Fifth Street, Philadelphia, U. S. A., and shall distinguish his performance by some motto, device, or other signature. With his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device, or other signature, and subscribed with the real name and place of residence of the author.

2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.

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